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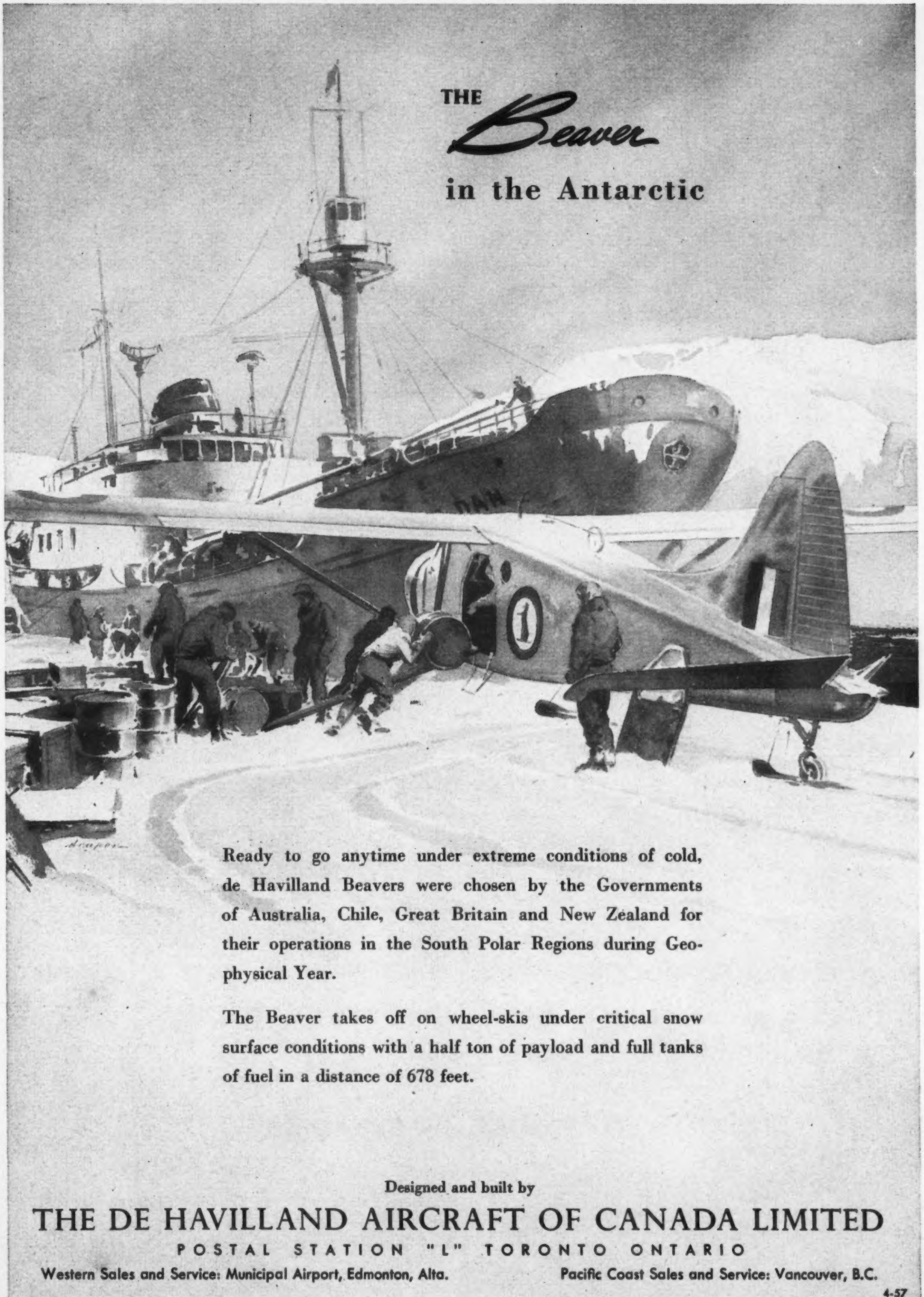
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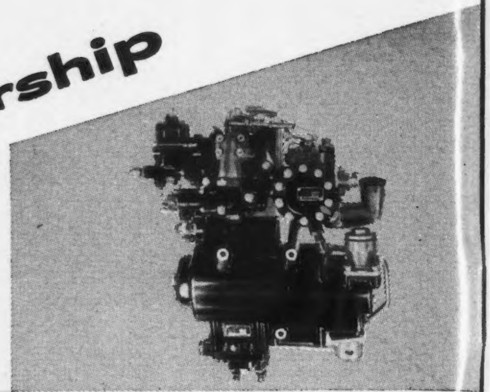

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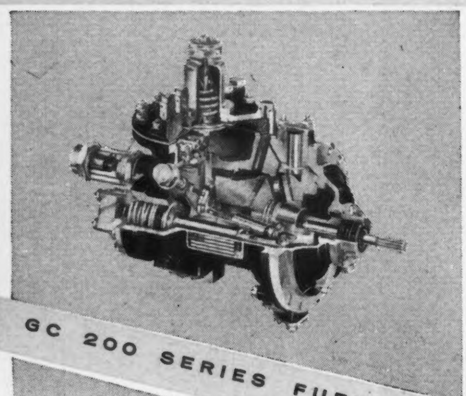

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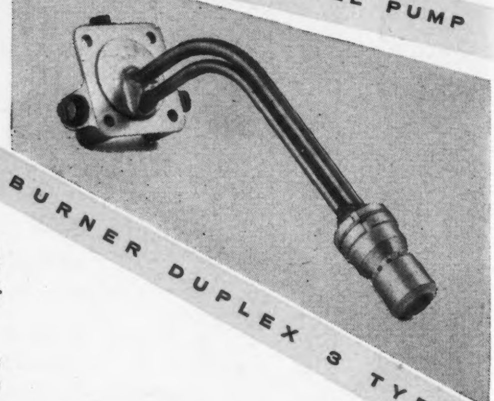

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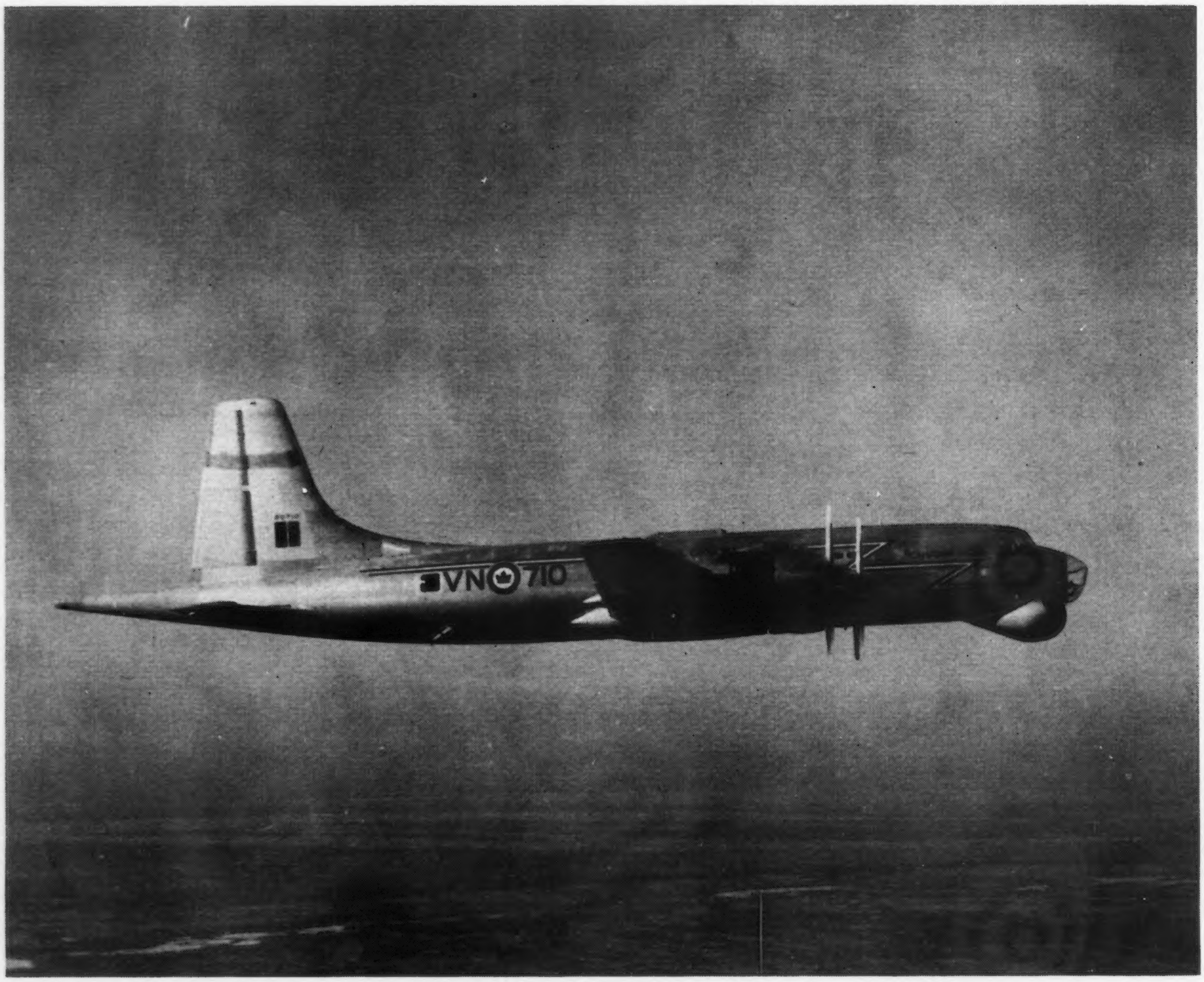
ARGUS



Canadair Argus Maritime Reconnaissance aircraft powered by four Wright Compound R-3350-30WA engines. This aircraft is based on the Bristol Britannia configuration.

EDITORIAL

HELP WANTED

MEMBERSHIP of the Institute imposes responsibilities upon all of us, not only to the Institute and to our fellow members but also to the "art, science and engineering relating to aeronautics".

These responsibilities are probably fairly well recognized and accepted by our members. There is no lack of enthusiasm and it is not uncommon for members to volunteer their services in our various activities. However, we cannot all present papers at meetings, or submit contributions to the Journal, or serve on committees, or even attend meetings regularly, and sometimes it is admittedly rather difficult to know what we can do. Well, the notice on page 166 offers a good suggestion.

Our Committees on Education and Training in the various Provinces are doing their utmost to stimulate interest in aeronautical training but they need the help of all of us in this task. If our own membership cannot appreciate the need, who can? We must take every opportunity to encourage young people to press on with their formal education to the limits of their ability. We must all recognize the danger that the country's aviation industry, on which our own livelihood depends, is in danger of being crippled in its growth and in its competitiveness by an inadequate supply of trained manpower. We, who try to promote the technical development of the aeronautical profession, must see to it that the profession does not wither for lack of nourishment.

At one time or another each of us has an opportunity to influence some promising young fellow who hasn't made up his mind what he is going to do. Let us take these opportunities, for the long-range benefit of the "art, science and engineering relating to aeronautics".

Steps are being taken by educational authorities and professional associations to establish recognized grades of academic attainment between matriculation and university graduation – in the realm of the Technologist and Technician. In the past many students have left school or taken non-technical courses because they have felt incapable of making the grade as Professional Engineers and have seen no point in "wasting" several years in an attempt foredoomed to failure. In future, these intermediate grades, each terminal in itself, will be available, making it much more attractive for the technically minded to continue their training as far as they possibly can. Those who are drawn by the external manifestations of engineering, the practical side rather than the broader theoretical aspects, can now find a niche for themselves in academic standing.

All the technical fields of aeronautics present something of a challenge. It is an old saying that "in the air nothing but perfection will do" and it follows that those who would serve the air must develop their knowledge and their skills to the ultimate. Even after our student years are passed we must go on learning so long as we are capable of doing so (and that will take most of us up to our retiring age). Let us, at the risk of being called bookworms, revive our thirst for knowledge and set ourselves a little homework. By so doing we shall not only benefit ourselves directly but set an example; we shall demonstrate the challenge and the young people of Canada were never backward at accepting challenges.

We owe it to ourselves and to the country to establish our own supply of technically trained people to man our aeronautical future. We cannot rely on immigration and we must allow for emigration. The demand for boys and girls to train themselves for an aeronautical career is a very pressing one; every member of the Institute can help in encouraging and guiding them.

STABILITY AND CONTROL PROBLEMS ASSOCIATED WITH SUPERSONIC AIRCRAFT†

by O. E. Michaelsen*

Canadair Limited

INTRODUCTION

It is generally recognized that the problems facing aircraft designers today are considerably more numerous and complex than they were twenty years ago. The possibility of achieving supersonic speed depends critically upon the aircraft geometry; thin wings and slender fuselages are essential with the presently prevailing engine thrust/weight ratios. Since a thin wing fundamentally is weaker and considerably more flexible than a thick wing of otherwise the same geometry and structural design, the thin wing must be short, stubby and highly tapered in order to possess sufficient strength and stiffness to withstand the changes in load distribution and the possible increases in dynamic pressure without too large an increase in wing weight per square foot. Fortunately a low aspect ratio wing is not too undesirable from the supersonic drag point of view. The drag due to lift at supersonic speed does increase with decreasing aspect ratio, but not nearly as severely as at subsonic speed. (It is, however, higher at supersonic speed than at subsonic speed for all values of aspect ratio.)

Equipment and payload in military aircraft have increased both with regard to weight and volume. Since the wing storage capacity has been decreased as a result of thinning the wing and increasing the wing structure volume, most of the equipment and payload have to be carried in the fuselage. If the aircraft has a single turbojet engine, the engine will normally be located in the aft end of the fuselage. The front part of the fuselage must then be long in order to store the necessary equipment and payload, and to obtain centre of gravity balance, without impairing the slenderness of the fuselage. If the aircraft has more than one powerplant, the engines may be located in nacelles out on the wing, but a long vertical tail arm becomes necessary to provide lateral trim during asymmetric thrust conditions.

Figure 1 illustrates the change in fighter aircraft geometry through the past fifteen years. The top left-hand picture shows the prototype version of the Lockheed F-104 Starfighter and the picture below shows the prototype version of the Convair F-102A. For comparison with World War II fighter aircraft, the famous Supermarine Spitfire Mk. V is shown in the picture to the right. The approximate ratios shown below the pictures should emphasize some of the main differences that exist with regard to geometry and loading.

The present article deals with some of the stability, control and handling problems that have arisen as a result of these drastic changes in aircraft configuration coupled with the advent of supersonic flight at high altitude. The article will be published in two parts. The present part deals with the longitudinal characteristics of supersonic aircraft.

The second part will deal with the lateral characteristics, the design of the flying control system and the methods used for solving the various stability problems.

LONGITUDINAL CHARACTERISTICS OF SUPERSONIC AIRCRAFT

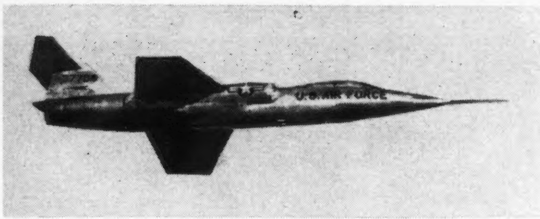
Static Stability and Trim

The static longitudinal stability problem of a supersonic aircraft is complicated by two main effects as compared with that of the conventional World War II fighter. The one effect results from the changes in aerodynamic load distribution that occur when the aircraft moves from the subsonic into the supersonic speed regime, and the second effect is due to the changes in geometry and relative size of the main components of the aircraft.

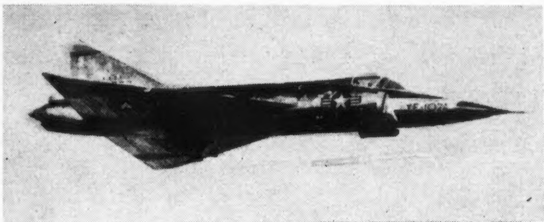
In the subsonic regime, the lift distribution over a wing is such that the aerodynamic centre is relatively far forward. If we consider a very thin wing of trapezoidal or elliptical planform, the aerodynamic centre is located at approximately the quarter-chord point from the leading edge of the mean aerodynamic chord. As we enter the transonic regime, that is where the local velocities over the wing reach the speed of sound and local shock waves are formed and the aerodynamic centre starts to move aft. (It should be noted that these effects may occur at flight speeds considerably below the speed of sound since the flow over the wing is accelerated. Local velocities equal to that of sound may thus be reached at flight Mach numbers of 0.8 or less.) As the speed is increased further, the rearward movement of

†Condensed from Quarterly Bulletin 1956(2), National Aeronautical Establishment, Ottawa. Received 15th April, 1957.

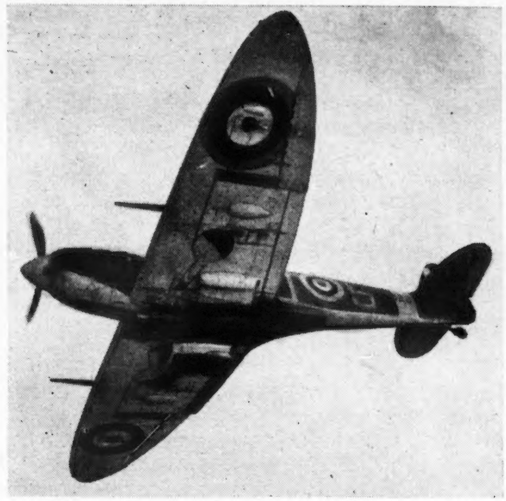
*Aerodynamics Section. Formerly with the National Aeronautical Establishment, Ottawa.



Prototype Lockheed F-104 Starfighter



Prototype Convair F-102A



Supermarine Spitfire MK V

COMPARISON OF CHARACTERISTIC VALUES WITH REGARD TO GEOMETRY AND LOADING FOR THE F-104,/F-102A AND THE SPITFIRE.

	F-104	F-102A	Spitfire
$\frac{\text{Wing Max. Thickness}}{\text{Wing Chord}}$	0.03–0.04	0.04	0.12
Aspect Ratio $\left(\frac{\text{Wing Span}^2}{\text{Wing Area}}\right)$	2.5	2.2	5.6
$\frac{\text{Fuselage Length}}{\text{Wing Span}}$	2.5	1.6	0.8
$\frac{\text{Fuselage Length in Front of C.G.}}{\text{Wing Span}}$	1.6	1.0	0.23
$\frac{\text{Vertical Tail Arm}}{\text{Fuselage Length in Front of C.G.}}$	0.44	0.35	2.1
$\frac{\text{Vertical Tail Surface Area}}{\text{Wing Area}}$	0.21	0.11	0.06
Max. Wing Loading, Lb./Sq. Ft.	75	45	25
$\frac{\text{Moment of Inertia in Roll}}{\text{Moment of Inertia in Pitch}}$	1/10	1/6	3/4

Figure 1
Comparison of supersonic fighter aircraft with typical World War II fighter

the aerodynamic centre continues until the mid-point of the mean aerodynamic chord is approached at a flight Mach number just above 1.0. Still further increases in speed will not affect the position of the aerodynamic centre appreciably. This rearward shift of the aerodynamic centre is general for any thin wing.

It will be clear that the degree of static longitudinal stability, normally referred to as the static margin, is a function of the location of the centre of gravity relative to the position of the neutral point of the aircraft. Although the position of the neutral point, that is the resultant aerodynamic centre, for the complete aircraft may be considerably different from the aerodynamic centre position of the wing alone, the neutral point undergoes a similar change to that of the wing aerodynamic centre through the transonic regime. Since the centre of gravity must be in front of the neutral point at subsonic speeds for static longitudinal stability, a large increase in the distance between the two points takes place as the speed is increased from subsonic to supersonic. This implies a large increase in static margin and the curves of pitching moment versus lift become extremely steep.

This large increase in static longitudinal stability through the transonic speed regime may appear, at first, to be beneficial. However, it should be noted that the aft position of the neutral point at supersonic speeds gives the same effect as that of a far forward location of the centre of gravity at subsonic speeds. Severe requirements are thus imposed on the pitching moment effectiveness of the longitudinal control in order to obtain trim at all useful values of lift at supersonic speeds.

Since the control lift contributes to the total lift of the aircraft, it can be shown that the net pitching moment

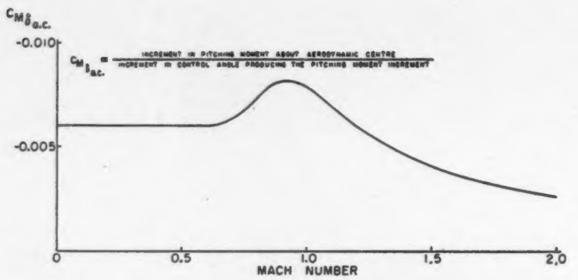


Figure 2

Typical variation of longitudinal control pitching moment effectiveness with Mach number

effectiveness, that is the effectiveness of the control in producing pitching moments while the total lift of the aircraft is kept the same, is determined by the location of the control lift relative to the neutral point and not to the centre of gravity. The resultant lift of the control experiences a similar, but smaller, rearward movement to that of the wing through the transonic regime, and the moment arm of the control becomes somewhat shorter at supersonic than at subsonic speed if the control is located behind the wing. The lift effectiveness of thin surfaces normally increases somewhat through the first part of the transonic regime, but then deteriorates rapidly with further increases in Mach number. The resultant variation of the net pitching moment effectiveness for an aft longitudinal control surface with Mach number may thus be shown in Figure 2. Figure 3 indicates the combined effects on trim of the increased static margin and the reduced control effectiveness that occur when the aircraft is moved from a subsonic to a supersonic Mach number. It is clear from this plot that the longitudinal control must be very effective indeed if trim at large values of lift coefficient is to be obtained at supersonic speeds.

For aircraft with conventional tail surfaces this is normally accomplished by incorporating an all-movable horizontal tailplane. A large control surface is thus obtained and reasonable control effectiveness can be achieved without an increase in tail size.

The large chordwise extension relative to span of a highly swept delta wing combined with the smaller travel of the aerodynamic centre with Mach number

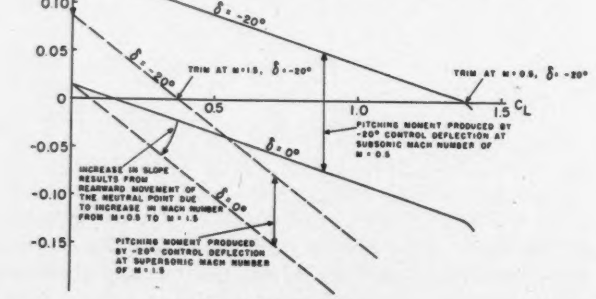


Figure 3

Typical effect of increased Mach number from (say) $M = 0.5$ to $M = 1.5$ on static longitudinal stability, control effectiveness and trim

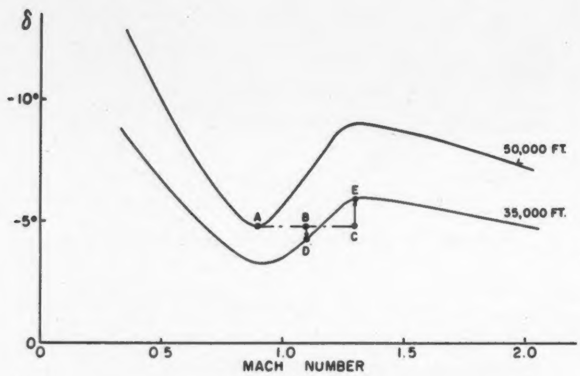


Figure 4

Typical variation of tailplane angle to trim at constant altitude versus Mach number

makes it possible to obtain longitudinal control by employing part span wing trailing edge elevators or full span elevons. Elevons serve simultaneously as elevators and ailerons, symmetric deflections providing longitudinal control and asymmetric deflections roll control. However, because of the relatively short moment arm of these controls compared with all-moving tailplanes, the control surfaces must be large in order to produce sufficiently large changes in control lift and considerable drag due to the trimming loads at supersonic speed may result. This trim drag is partly offset by the reduction in drag due to the absence of a horizontal tailplane.

Even if sufficient static longitudinal stability and control power exist for all values of lift coefficient and supersonic Mach number in question, the aircraft handling with regard to longitudinal trim may not be satisfactory everywhere. The changes in neutral point and control pitching moment effectiveness through the transonic and supersonic regimes are unavoidable and may introduce large difficulties to the pilot with regard to speed and altitude trim. Figure 4 shows typical curves of tailplane (or elevator) angle to trim in level flight against Mach number for two altitudes. It will be noted that trim instability at constant altitude exists for Mach numbers between 0.9 and 1.3 in so far as the pilot has to pull the stick back as the speed is increased in order to keep constant altitude. If the pilot is aware of this phenomenon in advance, it may not cause him too much trouble. It is more important that the aircraft should maintain its speed and altitude when unattended and that the change in flight path angle requires appropriate stick force, that is, a push force should be required to hold the aircraft in a dive. Let us assume that the aircraft represented by Figure 4 is trimmed at $M = 0.9$ at 50,000 ft (point A) and is put into a reasonably shallow dive. If, in descending from 50,000 ft to 35,000 ft, the forward speed increased only to $M = 1.1$, the tailplane angle has to be increased to point D in order to trim the aircraft at this new altitude, that is, the stick has to be pushed forward. If the tailplane angle is not altered (point B), the aircraft will tend to pull out of the dive. If, however, the speed increases to $M = 1.4$ during the dive, a pull force would be required to trim the aircraft at the new height (point E) and the aircraft would have a tendency to nose into the dive, if the tailplane angle remained

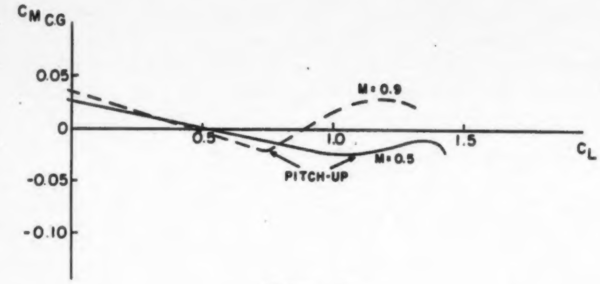


Figure 5
Typical variation of pitching moment with lift for aircraft exhibiting pitch-up

unchanged (point *C*). The condition for trim stability with regard to height and speed is thus that the change of Mach number with altitude due to acceleration must be less than the change of Mach number with altitude for trim at a constant tailplane angle. If this condition is fulfilled the aircraft will tend to return to its original height and speed when disturbed. The dynamic motion may, however, still be unstable. It is clear that the changes of thrust and drag with speed affect the aircraft trim stability and handling; increasing power will increase the change of Mach number with altitude due to acceleration and thus have a destabilizing effect whereas increasing drag will be stabilizing.

The longitudinal stability and trim problems, dealt with above, result from changes in flow that occur due to the compressibility of the air. These effects are fundamental in nature and cannot be completely avoided by changes in aircraft geometry although the difficulties that arise as a result of these effects are strongly influenced by the selection of aircraft configuration. The trends in supersonic aircraft geometry and configuration have, in turn, introduced certain static longitudinal stability problems at subsonic and low transonic speeds for large values of incidence. This common form of static longitudinal instability, known as "pitch-up", results from a forward movement of the neutral point at moderate to large values of angle of attack. Typical pitch-up curves for a subsonic and transonic Mach number are illustrated in Figure 5. The main contributory causes to pitch-up are:

(i) changes in the lift distribution at the wing alone with angle of attack
(ii) changes in the wing downwash with angle of attack producing destabilizing effects from the horizontal tail surfaces
(iii) changes in the fuselage pitching moment contribution with incidence
(iv) changes in downwash over the tailplane produced by the fuselage.

It is characteristic of swept-back wing planforms that they generally carry a larger proportion of the total lift near the wing tips than straight wings. This results from an effectively increasing induced angle of attack at the tips as they move downstream from the root section. This in turn implies that a considerable spanwise pressure gradient exists in such a direction that the flow over the upper surface of the wing will tend to turn out along the span. The thickness of the boundary layer will consequently increase towards the wing tip. The combination of large induced angles of attack and thick boundary layer at the wing tips means that these sections reach the stall angle, that is the angle of attack at which the flow separates from the upper surface, long before the inner portions of the wing. As the angle of attack of the wing is increased beyond the wing tip stall angle, a loss of lift at the tips results, whereas the lift over the inboard portions still increases. The resultant centre of lift for the wing thus moves rapidly forward and a forward shift in the aerodynamic centre results. The static margin is hence reduced and may become unstable if the neutral point of the aircraft moves in front of the centre of gravity.

It is found experimentally that it is the combination of sweepback and aspect ratio that determines whether or not a particular wing planform will exhibit pitch-up. There is no pitch-up tendency for any normal values of aspect ratio for a nearly straight wing whereas a wing with large sweepback must have a low value of aspect ratio in order to avoid pitch-up. For highly swept-back wings of large aspect ratio, the tips will stall at a low angle of attack and the wing will become strongly destabilizing at relatively low values of lift.

The values of sweep and aspect ratio for many aircraft presently in operation are close to, or on the "wrong" side of the subsonic pitch-up borderline. Some examples of aircraft with wing planforms close to the borderline are the F-86 Sabre, the Hawker Hunter, the Mig 15 and the F-102A. On the pitch-up side of the borderline are the B-47, the B-52, the Boeing 707, the DC-8 and the Russian Type 37 Bison and Type 39 Badger bombers. However, what has been said above applies strictly to plane, symmetrical wings. There are several ways by which the pitch-up tendency of a swept-back wing can be eliminated. An obvious remedy is to counteract the spanwise increase of the effective angle of attack by means of twisting or cambering the wing in such a fashion that the geometric incidence decreases towards the tip. For wings already in existence this is, of course, not possible without effectively constructing an entirely new wing and the methods that will be used in these cases generally involve some means of reducing the induced angle of attack of the outboard portions by shielding them aerodynamically from the inboard sections and/or increasing the effective stall angle of the wing tips. "Fixes" of this type include boundary layer fences, leading edge notches, wing tip leading edge extensions with or without droop, and boundary layer suction or blowing over the tips.

For aircraft with a low aspect ratio wing and conventional tail surfaces, pitch-up may occur as a result of unfavourable tailplane location. The lift of the wing produces a downwash behind the wing and if the tailplane is mounted within the region influenced by the downwash, the effective angle of attack at the tailplane is smaller than that of the wing. The variation of downwash behind low aspect ratio wings is large and may not be linear with angle of attack. Particularly highly swept delta wings, which by themselves may be longitudinally stable to beyond the value of maximum lift, produce large, non-linear downwash effects even at moderate values of lift. If a tailplane is mounted within the region of strong downwash from such a wing, it may be found

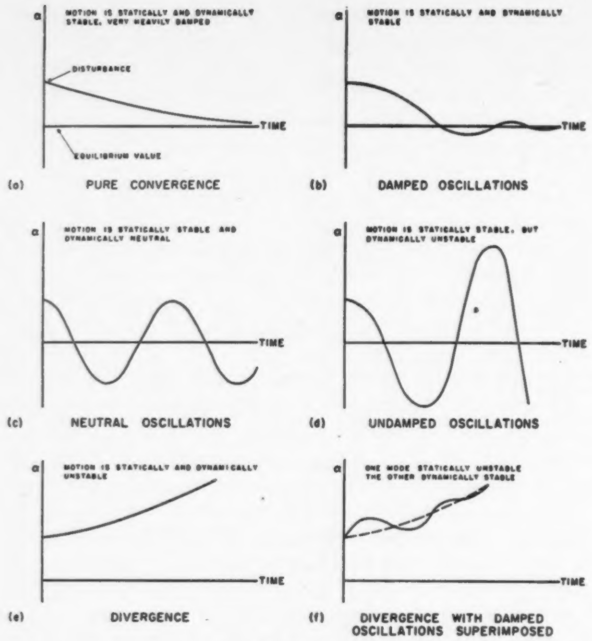


Figure 6
Typical modes of motion

that whereas a small stabilizing effect exists at low values of lift, a large destabilizing effect is obtained at moderate to high values of lift. The tailplane then contributes to pitch-up. The region of strongest downwash is normally slightly above the extended wing chord plane at low angles of attack and moves up somewhat with increasing incidence. The downwash generally decreases with increased distance aft of the wing. The best way to avoid unfavourable downwash variations with incidence at the tailplane is thus to place it as far behind the wing as possible and below the extended wing chord plane. This, however, may not be possible from other considerations and the tailplane is therefore frequently placed so high above the wing chord plane that it is always out of the regions of strong downwash.

In addition to being influenced by downwash from the wing, the horizontal tailplane may experience downwash resulting from fuselage vortices or from vortices created by wing-fuselage interference. Aircraft with long slender fuselages may, in particular, have large effects from fuselage vortices. These effects may be highly nonlinear with incidence and could thus contribute to tailplane pitch-up.

The variation of fuselage pitching moment contribution with incidence may also cause pitch-up if the body is large compared with the wing and tailplane and if the centre of gravity of the aircraft is far aft in the fuselage. The contribution of the fuselage to the total lift increases rapidly with incidence and although the centre of the lift simultaneously moves aft, the unstable fuselage pitching moment contribution may increase with incidence and thus contribute to pitch-up.

Although pitch-up could occur at any speed, practical experience indicates that the most critical range of Mach numbers from the pitch-up point of view is just before sonic speed. Pitch-up will normally not be a limitation in supersonic flight as a result of the general trend in the aft movement of the neutral point. If it did occur at supersonic speeds, this would probably imply that the aircraft was completely unstable in the subsonic and transonic regimes.

Longitudinal Dynamic Stability

In order to investigate the motion of any dynamic system, it is necessary first to establish that the system can be brought into a condition of equilibrium. For an aircraft this is referred to as the trimming of the aircraft. Once trim is obtained, it is necessary to ensure that a disturbance of this equilibrium must create forces and moments that tend to start the motion of the aircraft back towards the equilibrium condition. The tendency to return to the equilibrium condition is called the static stability of the aircraft. However, even if the aircraft's initial tendency is to return to the original condition, the resulting motion may be such that the equilibrium will not be reached. In this case the aeroplane is termed statically stable, but dynamically unstable. Figure 6 illustrates some of the possible modes of motion. The variable α may, for example, be the aircraft's angle of attack and the disturbance can be thought of as a sudden vertical gust. Since an aircraft has several degrees of freedom, the variation of any one variable with time will have several modes. It is possible that one mode will be stable whereas another simultaneously will be divergent. The resultant variation with time may thus be as indicated in Figure 6(f).

For motion in the plane of symmetry it can be shown that most aircraft have two characteristic modes of motion. The first one, known as the phugoid mode, shows up as a slow oscillation in the speed, flight path angle and altitude of the aircraft and is, in effect, the "hunting" of the aircraft about the speed-altitude trim position when it is disturbed from trim equilibrium. The period is normally of the order of a minute for a large fighter aircraft and the damping is light or non-existent. Since the period is long, the phugoid oscillation does not present any serious difficulty to the pilot provided the aircraft has reasonable speed-altitude trim characteristics as discussed in the previous section.

The second characteristic mode, referred to only as the short period oscillation, proceeds at essentially constant speed and altitude. The centre of gravity of the aircraft moves nearly along a straight line while the aircraft oscillates about the centre of gravity like a compound pendulum about its support pivot. It is essential for any fighter aircraft that this oscillation has heavy damping so that the fighter provides a steady gun platform, that is, the pilot or the electronic tracking system should be able to keep a steady aim on the target. (The term "steady gun platform" can perhaps be considered somewhat outdated since modern fighter armament usually consist of rockets and/or guided missiles.)

The frequency and damping of the short period oscillation vary over quite a wide range with increasing Mach number and altitude. The effect of increasing altitude is generally to increase the period and the time taken to damp the oscillations (the time taken to damp the oscillations to one-half of the initial amplitude is frequently used as a measure of damping), whereas the effect of increasing speed, neglecting compressibility

effects, is to decrease the period and the time taken to damp the oscillations. It is found by experience that it is the ratio of the time taken to damp the oscillations to the period that is important to the pilot in handling the aircraft, unless the period is either relatively long (greater than 10 seconds) or relatively short (less than one second). Although the ratio is affected by a large number of aircraft parameters as well as by altitude and speed, a first order approximation that applies reasonably well to fighter aircraft at medium to high altitudes at any speed is given by:

$$\frac{t_{\frac{1}{2}}}{T} = K\sqrt{\frac{-\frac{dC_m}{dC_L}}{\sigma C_{L\alpha}}} \tag{1}$$

where

$t_{\frac{1}{2}}$ is the time taken to damp the oscillations to one-half the initial amplitude in seconds

T is the period of the oscillations in seconds

K is assumed to be a constant for any given aircraft

$\frac{dC_m}{dC_L}$ is the static margin of the aircraft

σ is the ratio of the air density at the altitude in question to that at sea level

$C_{L\alpha}$ is the slope of the curve of the aircraft lift coefficient versus angle of attack.

In order for the pilot to handle the aircraft safely, it is found that the value of $t\frac{1}{2}/T$ must not be appreciably greater than unity. Considerably stricter requirements normally exist for operational reasons and the aircraft should probably have a ratio not exceeding ⅓ in order to provide a good gun platform.

The factor K depends mainly on the aircraft mean density and moment of inertia in pitch in addition to the ratio of the aerodynamic damping caused by the changes of pitch angle and angle of attack to the slope of the lift curve. Since the variation of the aerodynamic damping in pitch and angle of attack with Mach number normally is similar to that of the lift curve slope, the factor K remains roughly constant throughout the speed range. The largest contribution to the damping for an aircraft with a conventional tail configuration is derived from the horizontal tailplane. For a tailless aircraft, the damping of the short period oscillation is derived from the wing and fuselage alone and is consequently relatively small. The effective damping for any aircraft will depend on the relative values of the aerodynamic damping and the pitching moment of inertia of the aircraft. If the aircraft possesses a long, heavily loaded fuselage, the effective damping may be poor, particularly if the aircraft is of the tailless configuration.

The above expression indicates clearly why the short period oscillation has become of increasing concern to aircraft designers in the past few years. World War II aircraft normally had excellent damping of this oscillation and its existence was hardly ever realized by the pilot. However, summing up the typical changes in the various parameters in Eq. (1) that have occurred as a result of the past fifteen years' developments, the result is somewhat different. The value of the factor K has been about doubled as a result of the changes in aircraft geometry and loading. The value of the static margin has increased by a factor of three or four as a result of supersonic flight. The lift curve slope has decreased by a factor of about two or more as a combined result of decreased aspect ratio and the deterioration of lift curve slope with increasing supersonic Mach number. Finally, the increase in operational altitude from 35,000 ft to 65,000 ft has reduced the value of the air density ratio by a factor of four. Thus, comparing a Spitfire with a typical supersonic fighter, both flying at their respective top speed and operational ceiling, it is found that the value of $t\frac{1}{2}/T$ for the supersonic fighter is about ten times as large as that for the Spitfire. From the point of view of operational requirements it appears that any supersonic fighter aircraft will require some artificial augmentation of the pitch damping at high speeds and altitudes. This can be achieved by oscillating the tailplane (or elevator) or an auxiliary surface in such a manner as to produce a damping moment in pitch. The programming of the deflection of the damping control surface may be obtained from a rate gyro possibly in connection with an angle of attack vane. A hydraulic servo actuator deflects the control surface upon signal from the gyro or the angle of attack vane. It may be necessary in certain cases to incorporate electronic networks to obtain the proper response and damping characteristics of the control system as well as of the aircraft itself.

Another aspect of supersonic aircraft handling in pitch which may cause the pilot some difficulty is the increasing tendency of aircraft to "mush". An aircraft is said to be "mushing" if the change in the angle of attack is large relative to the change in flight path angle when the stick is moved. In the past this effect could only be noticed near the stall where the lift varies slowly with changes in the angle of attack. The tendency of an aircraft to mush depends on its wing loading and lift curve slope as well as the speed and altitude at which it flies. The present trends of increased wing loading, decreased lift curve slope and increased altitude all tend to produce mushing, whereas increases in speed decrease this tendency. However, the beneficial effects of speed may be offset by the rapid decrease of lift curve slope with increasing supersonic Mach number, and mushing may be disconcerting to the pilot at any speed at high altitude. This would upset his aiming capabilities, especially if the tendency to mush is connected with low damping, and fully automatic aiming devices may be required.

(To be continued in the next issue)

OPERATIONAL USE OF TACAN†

by M. Block*

Federal Telephone and Radio Company

INTRODUCTION

In the early days of aviation the need for navigational aids was visualized solely to assist pilots in proceeding from location to location. As the aviation industry expanded, a new service, air traffic control (ATC), came into being. Navigational aids became increasingly important as they were utilized:

(1) in designing the route structure to accommodate the aircraft flying in the ATC system, and

(2) as a primary ATC tool by the controller.

Today we are on the threshold of employing the optimum in ground based air navigation aids, Tacan. As presently constituted, this equipment which provides continuous, precise position information, will afford many advantages in aircraft operations and air traffic control. Tacan has the further capability of adding other navigational (localizer, glide path, marker, ATC transponder) and communication functions to give us the completely integrated system. While the Tacan Data Link is still a confidential project, we have obtained an officially cleared release which is as follows:

> "Tacan has been planned from the very beginning of its development as a coordinated system with a capacity and duty cycle such that an air traffic control information system can be added to it without increasing the frequency spectrum required and without adding any radio equipment to the system. This traffic control function can be such that the ground would know all relevant facts about the position and conditions of all aircraft tuned to a Tacan station. At the same time the ground could have the ability to communicate to any given airplane information of like nature or useful to traffic control."

EQUIPMENT

To briefly describe the equipment, Tacan, a code word for "tactical air navigation", is a radio air navigation system of the polar coordinate type operating in the UHF (1,000 Mc) band. Position information is presented in two dimensions, distance and direction, from a single point. Tacan has 126 crystal controlled, two-way operating channels available for assignment. For air-to-ground transmissions (required only for the distance function) there are 126 frequencies within the band 1,025 Mc to 1,150 Mc. For ground-air transmissions (serving both bearing and distance functions) there are 63 frequencies in the band 962 Mc to 1,024 Mc, plus 63 frequencies in the band 1,151-1,213 Mc. The Tacan channels are "clear frequencies". Pulse coding is used for the purpose of noise reduction and the multiplexing of the bearing function on the DME channels. It is recognized as the navigational aid which most closely meets the requirements specified by the Radio Technical Commission for Aeronautics[1]. The equipment was developed by Federal Telecommunication Laboratories and manufactured by Federal Telephone and Radio Company, divisions of International Telephone and Telegraph Corporation.

AIRCRAFT OPERATIONS

The earliest advantages to be gained by the installation and use of Tacan will be realized in aircraft operations. The manual, *Air Force-Navy-CAA Criteria for Standard Instrument Approach Procedures*, dated July 1, 1954, is presently under revision to include provisions for the use of Rho-Theta navigation aids. It is anticipated that the continuous precise position information of such aids will permit:

(1) greater flexibility in establishment of instrument approach procedures,

(2) lowering of minimum instrument approach altitudes,

(3) establishment of orbiting approaches,

(4) establishment of instrument approach procedures at locations not presently authorized such service, and

(5) more effective use of straight-in approaches.

Such action will express itself in more efficient and increased operations to the aircraft operator. At locations having multiple airports, less ground equipment will be required to provide a more simplified operation with less frequency changing (frequently a cause of radio failure). The flexibility in operation allowed by the use of Tacan will serve to ease the noise abatement problem by permitting approaches which will circumvent the highly populated areas. Greater flexibility in and reduced airspace required for holding will also expedite aircraft movements. In addition to the benefits to be realized in approaches, increased discrete departure routes will permit more aircraft to operate.

The advantages listed above can be realized by individual aircraft when ground installations become available, aircraft are suitably equipped, and procedures are developed for specific locations. In the field of air traffic control, however, the advantages that will be discussed will not be realized until a substantial majority of the users are equipped.

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The air traffic control system has two major divisions; namely, *terminal*, which covers approach and departure procedures in the vicinity of airports, and *en route*, which covers that portion of flight conducted between airports.

TERMINAL PROBLEM AREAS

The major terminal problem areas have been resolved largely by the use of radar. Radar and Tacan have much in common in that the precise position of aircraft, afforded by both equipments, allows for more efficient use of the airspace. This, in turn, expresses itself in terms of a lower landing interval and expedited departures. As a consequence, high density and complicated airports, such as Washington and Chicago, have been aproaching their Visual Flight Rule handling capability during Instrument Flight Rule weather conditions.

The remaining restrictions to the high density terminal problems are the airport acceptance rate and the inability of the en route portion to feed aircraft to and accept aircraft from the terminal area at the desired rates. At these locations, Tacan may be employed to feed aircraft into the radar system at any rate desired. By permitting establishment of numerous independent inbound and outbound routes, Tacan will not only facilitate arrivals and departures, but lessen controller workload by reducing air/ground communications and intercontroller coordination. Tacan will further reduce the controller's workload as accurate airborne position information will simplify radar identification.

While radar is recognized as a most valuable tool, much concern has been expressed over its target saturation, susceptibility to precipitation, altitude and range limitations. It is evident that radar must be supported by nav-aids compatible with its capability. Various studies conducted by the research laboratories have indicated that a highly proficient controller can handle a maximum of six aircraft when using radar. This figure will not meet the requirements of any of the major terminals. Consequently, aids of various kinds, radio ranges, homing beacons, intersections and fan markers are used to establish fixes and otherwise relieve the controller from furnishing guidance to the pilot.

The above mentioned aids, which establish fixes and routes to guide aircraft, are fixed and do not meet the need for flexibility required in today's operation because of the proximity of airports, adjacent airways, and the difference in performance of aircraft operating in the same area. Tacan will supply the fix information with considerably more flexibility and save airspace in the process. An example of this is the airspace reserved for holding patterns. Using existing aids, CAA Technical Order TSO N 20A requires that a racetrack pattern 19 miles long and 8 miles wide be reserved for aircraft holding below 20,000 ft; for an aircraft holding at 20,000 ft, approximately 608 square miles of airspace are reserved for the holding pattern. The accurate and multifold holding patterns that Tacan permits will reduce significantly the airspace required for this action and allow aircraft to be held at the optimum location dependent on the position of other airports, adjacent airways, and the traffic picture in general.

At non-radar locations, Tacan will permit operations closely approximating that of radar. In addition to the capabilities cited above, the distance measuring capability may allow use of distance as the unit of measurement rather than time, which is used at such locations at present. Dependent on the capability of the pilot to fly the system, the equipment has the inherent capability of allowing a landing interval to be maintained similar to that of radar.

The military has been pressing for more expeditious handling of its jet aircraft for some time. Now, with the advent of civil jet aircraft, the Air Transport Association, representing the scheduled air carriers, is also expressing the need for procedures more suitable for jet operations. Tacan, because of its continuous precise position information, will permit establishment of more efficient jet aircraft approach and departure procedures in relation to other traffic. This can be accomplished by the use of orbiting paths for the traffic concerned, establishment of discrete departure and arrival routes and precise channeling of crossing traffic.

EN ROUTE PROBLEM AREAS

The CAA has done and is doing a truly remarkable job in the field of air traffic control. However, the rapid development of aircraft, both in performance and numbers, has been so great that the ATC system has not been able to keep pace with the operational demand. A prominent shortcoming has been the inadequacy of nav-aids. This inadequacy has contributed to the following factors which adversely affect the control of air traffic:

(1) current separation standards,
(2) estimated position of aircraft,
(3) poor display of traffic information to the air traffic controller,
(4) lack of flexibility in the airway structure, and
(5) inefficient use of the airspace.

Current Separation Standards

This feature of the existing system is causing airspace to shrink in direct proportion to the increase of speed of aircraft. The Federal Airways Manual of Operations, *ANC Procedures for the Control of Air Traffic,* which establishes separation standards, requires a minimum of 10 minutes longitudinal separation between aircraft with similar speed characteristics following the same flight path. When aircraft made good a ground speed of 180 mph, this time represented 30 miles of airspace. Aircraft making good a ground speed of 420 mph, which is not uncommon today, have 70 miles of airspace reserved. In the case of B-47's, the total number of which exceeds all the scheduled air-carrier aircraft put together, approximately 100 miles are required. In so far as crossing traffic is concerned, these figures are doubled as airspace is reserved 10 minutes in front as well as behind. The military has broken Mach 2 and is talking in terms of Mach 3, or roughly 2,000 knots. It is readily apparent that unless something is done to change our separation standards, we will soon run out of airspace.

Estimated Position of Aircraft

The 10 minute time separation requirement was established because of the lack of knowledge on the part of both the controller and the pilot of the aircraft's precise position. The CAA airway route structure generally provides for a radio fix every 60 to 70 miles. In developing

the separation standard, it was considered probable that the pilot and the controller could miss their estimate over the next fix (the basis for the control system) by plus or minus 3 minutes. Considering two aircraft involved, this allowed 6 minutes, to which had to be added 1 minute clock error for reporting on either side of the 30 second marker. To allow for other contingencies, differences in equipment, airborne and ground, and the hearing acuity of the pilots concerned, an additional 3 minutes was allowed. Although both the military and civil aviation interests are alarmed about the considerable amount of airspace reserved for high performance aircraft, neither has requested a lowering of the standards. Tacan, through its distance measuring capability, may permit distance rather than time to be used as the unit of measurement with consequent airspace saving. A similar condition to the longitudinal separation standard exists in regard to the lateral separation standard. The normal lateral separation for en route aircraft is expressed in the 10 mile airway. However, as a result of extensive experience with the inability of pilots of high performance aircraft to fly precisely, again because of the inadequacy of the nav-aid, by actual practice, the CAA reserves considerable additional airspace. Tacan, with its precise azimuth information, could remedy this situation.

Poor Display of Traffic Information to the Air Traffic Controller

The present means of transferring, processing and displaying of aircraft data has long been recognized as one of the most severe bottlenecks in developing an efficient ATC system. The present system is designed to accommodate the aircraft position reporting procedure and airway route structure which, in turn, is based on the nav-aid structure. This system concept came into being in approximately 1940 and is essentially the same today, although there is an increasing demand for enlargement of the system capacity. The CAA, in handling a tenfold increase in traffic since the inception of this system, accomplished this by breaking the job down into smaller and smaller areas, and the hiring of more people. This has created an additional coordination problem which also requires more people. It is the general opinion that the manual posting of flight information has gone as far as it possibly can. A more dynamic display based on frequent, accurate position information, provided by precise Rho-Theta aids and used in conjunction with a more rapid means of communications, is required.

Lack of Flexibility in the Airway Structure

The present fixed airway structure is limited in design to the number of fixes available for determination of position. Ability to determine position is the key to establishment of good routings. Other than Rho-Theta aids require additional facilities for this purpose. Consequently, adding additional airways is expensive and time consuming. In today's operation, as an airway becomes saturated, the control center responsible for its operation will restrict the number of aircraft that desire to use it. As this back-up of traffic occurs, the ATC problems become acute and extremely complicated, requiring extensive controller coordination. In scope, a back-up of traffic in the New York metropolitan area affects air traffic throughout the U.S.A. Controllers have often stated that the secret to good operation is to keep the traffic moving.

Additionally, one of the features of air travel is the ability to get somewhere in a hurry. Man-made stumbling blocks are now provided by the ATC system because of the inadequacy of navigational aids. For example, a jet aircraft en route to a southerly location from Andrews Air Force Base will frequently climb on a northerly heading to cruising altitude. No doubt many of you have received clearances from ATC agencies specifying routes other than those requested. In this day of minimum fuel aircraft, more flexibility must be realized to achieve maximum use of the airspace for the benefit of all users.

Tacan, with its continuous, accurate position information, will permit greater flexibility in operations, more and better routings, rearrangement of routes dependent on traffic flow, and reduce controller coordination by permitting expanded use of one way airways.

Inefficient Use of the Airspace

The CAA is responsible for controlling only aircraft operating in controlled airspace. Aircraft desiring ATC service must adhere to the confines of such areas. Normally, the designation of controlled airspace is dependent on availability of adequate communications and navigation facilities. Due to the limitations of existing nav-aids, both airborne and ground, inefficient use is being made of the available airspace. For example, a relatively small amount of the available airspace is designated as controlled airspace. The distance capability of Tacan will permit lowering of minimum en route altitude and the development of more efficient airspace utilization through use of curved airways to circumvent high density terminal areas. The more precise azimuth portion of Tacan will make better use of the available airspace by requiring a lesser lateral separation than any other known aid. For example, a 15 degree lateral separation standard has been established for VOR when climbing or descending or passing an aircraft. This criteria is based on a system error of plus or minus 4 degrees, plus or minus 1 degree pilotage, and a 5 degree buffer area. Tacan has a system error of less than plus or minus 1 degree; therefore, using the other factors established for VOR should permit a 9 degree lateral separation standard for Tacan. In highly congested areas, such as northeastern U.S.A., this can prove to be a most important factor.

The use of an off-course computer in conjunction with Tacan, by permitting multiple parallel courses, will permit the development of an ATC concept based on area coverage, with attendant flexibility, frequency and equipment saving.

Tacan, the coordinated system, will permit the parallel development in air navigation-traffic control required to meet the operational demand of all users of the airspace in the foreseeable future.

REFERENCE

(1) *Air Traffic Control,* Paper 27-48/DO-12, RTCA Special Committee 31, May 12, 1948.

AN INTRODUCTION TO AUTOMATIC ELECTRONIC COMPUTING FOR ENGINEERING CALCULATIONS†

by B. J. Kaganov*

Canadair Limited

INTRODUCTION

THE rapidly increasing use of automatic computing has aroused curiosity as to its basic concepts. This paper will add but little to the art of automatic computing. It is directed towards the neophyte and will deal with historical background and basic operations.

The thorough investigation of a design problem involves complicated mathematical formulae. The engineer, almost always, states his problem in the language of mathematics in order to condense the entire matter into a few short algebraic statements. In order to reach a solution and compile useful data from these mathematical equations, it is necessary to add, subtract, multiply and divide in accordance with the basic functions of the equations.

Before the advent of high speed computers, these lengthy calculations were so time consuming and costly that only the simpler problems could be undertaken.

The two major categories of automatic computing are usually referred to (a) that which deals in numbers only or the digital, and (b) the analog which deals in physical variables. There is much work being done on analog to digital convertors and digital to analog convertors. This equipment is usually known as ADDA.

The use of automatic methods of computing probably dates back as much as 5,000 years ago in the Tigris and Euphrates Valley and in Egypt as early as 460 B.C. where an early type of abacus was used. In its first form, the abacus consisted of a clay board with grooves into which small stones were placed. Further development of this first type of digital computer evolved into the form of wire frame with beads. It is of interest to note that the word calculate is derived from the pebbles or calculi on the wires of an abacus. This form of abacus appeared in Rome, China and Japan and is still a favoured form of computer in oriental countries.

The planimeter, an analog device, first appeared in 1814 after its invention by J. A. Hermann, a Bavarian engineer. Of course we are all familiar with and have used for many years the slide rule which is now one of the simplest methods of analog computation.

DIGITAL COMPUTERS

The evolution of the digital computer passed through many stages from the simple adding machine to the desk calculator, e.g. Marchant, Friden, Monroe etc. The first large scale general purpose digital computer was completed at Harvard University in 1944. The machine was built jointly by Harvard and I.B.M. and is known as the Harvard Mark I calculator.

It is quite possible to exaggerate the speed which can be achieved in computing with a desk calculator. In 1946 the U.S. Army staged a competition involving ordinary arithmetic between one of their Japanese clerks using an abacus and an American on a modern calculating machine. The Japanese won every time.

The digital computer works directly with numbers. The desk calculator adds by the addition of revolutions or fractions thereof. Multiplication is just an extension of the principle of addition or subtraction, which is negative addition. The size and value of the problems the machines can handle efficiently are based on the speed with which they can add. Complex differential equations are programmed by repeatedly refining an approximation. A complex problem worked on a desk calculator or mechanical digital machine whose addition operation is timed in seconds may prove most difficult to solve, whereas the same problem on a machine that performs the operation in milliseconds or microseconds becomes a matter of facile solution.

Digital computers may be divided into two classes, general purpose and specialized. The specialized computers, such as computing gasoline service pumps and parimutuel machines, are quite familiar to most of you.

Of more interest are the general purpose computers and those in the mechanical class are well known. These would be the abacus and the desk calculator. The electronic digital computer, such as the I.B.M. series from the Card Programmed Calculator, 650 to 700 series, the Eniac, Univac, Datatron etc., are of absorbing and growing interest to the engineering profession. Although the basic operation of such machines is still by addition,

†Paper read before the Montreal Branch of the C.A.I. on the 16th January, 1957.

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the speed in which an operation is performed is such that mathematical equations heretofore believed impossible of solution can now be attempted.

One of the first electronic type computers was the I.B.M. 604 or its more advanced model to include storage, the C.P.C., which stands for Card Programmed Calculator. The machine when used in engineering is wired by special purpose boards to give nine basic operations, such as $A + B = C$, $A.B. = C$ etc. The machine operates in decimal code. It may be worthwhile at this time to explain the difference between a decimal and binary system.

Decimal and Binary Systems

A decimal system is the one we use daily in all our basic handling of numbers, whether we are buying something in the local store or doing longhand arithmetic. It works with the number ten, so that 100 is equal to 10^2 and 1,000 is equal to 10^3. The machine operates by using four basic electronic tubes for number determination. With the digits 8, 4, 2, 1, these tubes are vertical so that if 5 is required, tubes 4 and 1 would be used. It can be seen that any combination of the digit 1 to 15 can be obtained, but the computer only uses 1 to 9. To call for the number 17263, the tube array would be as in Figure 1.

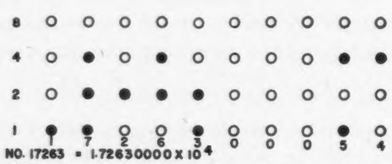

Figure 1

The base of a number system is defined as the number of units in a decimal place or a given digits place. Thus, if the base is two, two units in a given place are denoted by a unit in a first higher place; two units in the first higher place are denoted by a unit in a still higher place. Similarly, if the base is ten, ten units in a first place (designated units) are denoted by a unit in the first higher place (called "tens") and so on.

The base requiring the least number of units on which a system of numbers can be predicated is two and such a system is known as binary.

Two symbols (0 and 1) are used to represent all quantities instead of ten symbols as in the decimal system. Counting is started in the binary system in the same way as in the decimal system with 0 for zero and 1 for one. But at two in the binary system, it is found that there are no more symbols. It is then necessary to take the same move at two in the binary system that is taken at ten in the decimal system. This move is to place a 1 in the first position to the left and start again with a 0 in the original position. Therefore, 10 in the binary system is the equivalent of 2 in the decimal system. Counting is continued in an analogous manner with a carry to the next higher order every time a two is reached instead of every time a ten is reached.

To evaluate a number on the binary system, reference is made to Figure 2.

POWERS OF 2

$2^0 = 1$
$2^1 = 2$
$2^2 = 4$
$2^3 = 8$
$2^4 = 16$
$2^5 = 32$
$2^6 = 64$
$2^7 = 128$
$2^8 = 256$
$2^9 = 512$
$2^{10} = 1024$

NO. 120 IN BINARY SYSTEM

2^6	2^5	2^4	2^3	2^2	2^1	2^0	
64	32	16	8	0.	0	0	= 120
1	1	1	1	0	0	0	= 120

NO. 119

1	1	1	0	1	1	1	= 119
64	32	16	0	4	2	1	= 119

NO. 200

2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0	
128	64	0	0	8	0	0	0	= 200
1	1	0	0	1	0	0	0	= 200

Figure 2

In the binary system the indication of 1 or 0 is whether that power of two is used to obtain the number. It might be mentioned that this can just as easily be symbolized by on and off, or yes and no. Actually this is automatically done by the machine. Coding may still be done in the decimal system, but knowledge of the binary system is necessary in "debugging" the program when the machine operates in a binary number system.

Card Programmed Calculator

To get back to the C.P.C., the operations that were originally wired into the board are selected by code printing in cards. Therefore, to solve a problem a set of instructions cards is punched. One card is punched for each operation. Thus, the sequence of operations — the program — is determined by the instruction deck.

To change from one job or problem to another, it is necessary to change only the instruction deck. These standard problems or sub-routines are stored in a library for usage over and over again.

The C.P.C. (Figure 3) consists of four or more standard units, namely, an accounting machine, an electronic calculator, a high speed punch and auxiliary storage units. The storage unit is a numerical store and has the capacity of storing 16 ten-position numbers. One or two additional storage units may be added to increase the numerical storage capacity. This is of great importance in the solving of engineering problems. Input to the machine is by punched I.B.M. cards. The card contains control punches and data fields. The control punches determine the operation to be performed and the location of the input factors, as well as whether the output results will be printed, punched or stored. The data fields contain the original factors to be printed, accumulated, sent to the calculator or stored for future use.

The output from the C.P.C., consisting of source data, intermediate and final results, may be printed or punched in I.B.M. cards or both. The punched cards may be used as input data to the calculator at a later

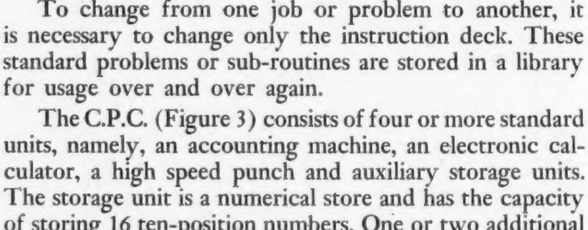

Figure 3
IBM Card Programmed Electronic Calculator

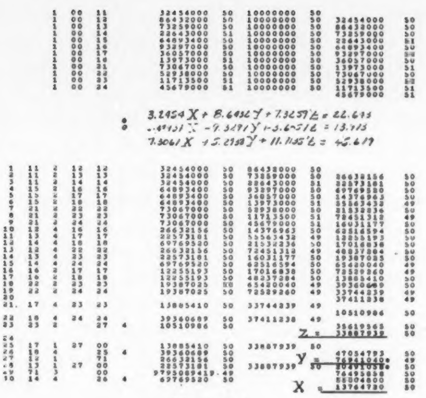

Figure 4

time and they may also be used for operations in other standard I.B.M. equipment.

A sample solution for three simultaneous equations is shown in Figure 4. The elapsed time to solve this problem on a C.P.C. was three minutes. The keypunch operator used 2½ minutes to punch the constants on the cards and the machine took 30 seconds for the solution. The sub-routine was obtained from the library. The solution of this problem would take an engineer or mathematician, assuming no arithmetical errors, upwards of 30 minutes. As we climb the scale of more complicated problems, time saving is magnified exponentially.

If the computation were to be performed by a human computer, it would be possible to communicate the problem to him in a series of instructions or orders, each specifying an elementary arithmetical operation. The same has to be done to the machine. A sequence of orders is called the program. The program must contain everything necessary to enable the machine to perform the required calculations, every contingency must be foreseen. A human computer, based on past experience, is capable of reasonable adjustment of his instructions when faced with an unforeseen situation. This is not the case with a machine. An automatic computing machine can perform only a very limited number of basic operations, the simplest mathematical calculation requiring an extended sequence of orders.

Programming is the most important job in a computing setup since an optimum program saves machine time. On complicated and long problems, where the program may entail thousands of cards, debugging the program may take as long as setting up the program.

I.B.M. 650 and Datatron

The next advancement in digital computers was, of course, necessitated by the need of more memory or storage and higher speeds of operation. This, of course, is the everlasting problem of digital computer advancement. The I.B.M. 650 and the ElectroData Corporation Datatron (Figure 5) can be considered as the next step forward from the C.P.C. Both machines are similar in operation although the Datatron has a 4,080 word memory and the 650, a 2,000 word memory. The two machines are considered as fully automatic digital computers. The programs are stored in the internal memory. The Datatron, in common with other fully automatic digital computers, stores instructions, coded in numerical form, and the numbers with which it is to operate, interchangeable in its internal memory. It makes comparisons between numbers and instructions and alters the sequence of operations accordingly. These two basic capabilities enable this computer to:

(a) perform arithmetic and logical operations on either instructions or numbers in accordance with sequences of instructions stored in its memory,

(b) select alternate sequences of instructions depending upon the results of a comparison between the two numbers or instruction, and

(c) alter or modify one or more instructions in accordance with a fixed sequence of instructions.

The solution of computer problems, as was stated before, involves repetitions of relatively few basic sequences of operations. The hundreds of thousands of individual operations required for the solution of a typical problem may be carried out entirely automatically by the computer in accordance with an original set of perhaps only a few hundred instructions. The ability of this type of computer to perform arithmetic and logic (including selection of alternate sequences and alteration of instructions) at the rate of several hundred operations per second increases its value over the C.P.C. ten to one hundred fold.

The Datatron, like the C.P.C. and 650, operates in the decimal number system using the four binary digits 8, 4, 2 and 1. The internal operation of a machine using the decimal system significantly simplifies the preparation of the instructions, eliminates the necessity for conversion to and from the decimal system for input and output and facilitates the location of coding and machine errors, should they occur.

Whereas the C.P.C. has only ten basic commands which the machine can be given, the Datatron has upwards of 60. The latter also has internal checking such that the appearance of an unexpected arithmetic overflow or the appearance of a forbidden combination of digits, that is, one representing the numbers 10-15, will stop computer operation.

Besides using a punch card input and output, this machine uses also either paper or magnetic tape. Whereas with punched cards the maximum rate of input is 200 cards per minute or 300 decimal characters per second, paper tape has a speed of 540 decimal characters per

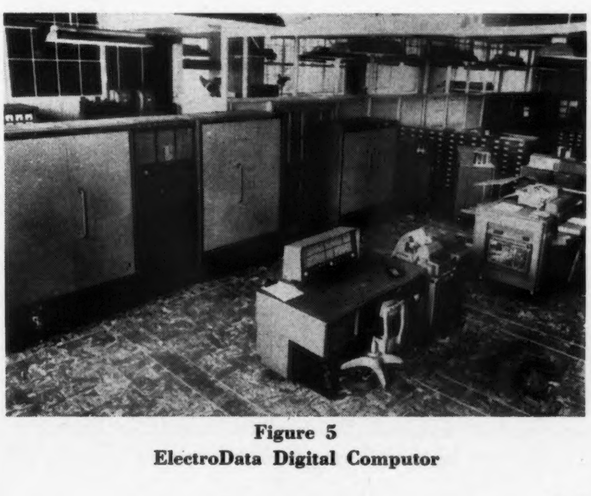

Figure 5
ElectroData Digital Computor

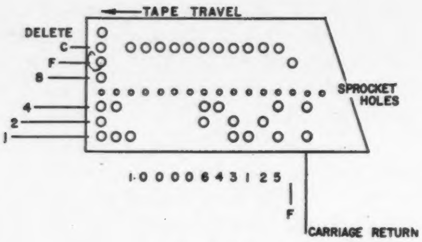

Figure 6

second. The entire 4,000 word main storage can be filled in about 1.5 minutes. Information to be read into the computer is punched on paper tape in serial decimal digits. Each word on the tape occupies thirteen decimal digit positions: one for the algebraic sign; ten for digits of the word; one for the finish punch; and one for a carriage – return character, which is ignored by the computer.

A sample selection of the upper side of the tape as it goes into the photoelectric reader or flexowriter is shown in Figure 6.

The four lower channels contain the decimal digit value. The fifth channel contains the *F* or finish punch which signals the end of an 11 digit word. The sixth channel contains the *C* (or 'clock') punches which indicate to the computer that the contents of the lower four channels are to be accepted at the same time as a bit or binary coded digit. The lower four channels will be read into the computer only when accompanied by a *C* punch. The seventh channel is a delete punch indicating that the other channels are to be ignored when read by a tape preparation unit. This punch is an instruction to the Flexowriter only and is not read by the photoelectric reader.

To review at this point, the 604 calculator is fundamentally an arithmetic unit operating on two high speed storages. The C.P.C. is an electronic computer with an arithmetic unit operating on two high speed storages, but in addition there is available to the arithmetic unit approximately 35 mechanical slow speed storages. This makes the C.P.C. approximately four times more powerful than the 604. The Datatron is an electronic computer with an arithmetic unit of 4,080 high speed storages.

A computer is capable of 'remembering' certain numbers and instructions and of calling these back into the computing cycle thereby reducing the time consuming card handling which otherwise would be necessary. The Datatron or 650 is equivalent to 2,000 desk calculators. A 12 × 12 matrix will take two ordinary mathematicians 32 hours to solve. The Datatron will do it in ten minutes. A 42 × 42 matrix will take two men working 2,744 hours, while the machine will do it in 1½ hours.

To sum up digital computing, mention should be made of the newest scientific digital computers which are all electronic including memory. The memories used on the C.P.C. 650 and Datatron are of the mechanical drum type.

I.B.M. 704

The I.B.M. 704 is a large scale binary electronic computer which is either under the direct control of an operator or under the control of a stored program.

The machine was designed for the higher speeds and larger capacities required by problems of increasing complexity and size which confronted industry and science. These problems include engineering development, scientific research, production scheduling and control, logistics and many others. In order to achieve maximum versatility, every function of the machine is under the control of the stored program. This allows the machine to execute instructions at the rate of about 40,000 per second on most problems.

In discussing the 650 and Datatron, advantages for using a decimal system were quoted. The 704 uses a binary system to achieve greater speed and efficiency. The input and output, however, may be accomplished directly on standard I.B.M. cards in the familiar decimal number system by programming.

Besides its main logical and arithmetic control unit, the machine possesses many storage devices which in descending order of speed are: (a) magnetic core storage (111,000 characters/sec), (b) magnetic drum storage (25,000/sec) and (c) magnetic tape storage (15,000/sec). There are also peripheral units available which are capable of transferring information from tape to printer, punched cards to tape and tape to punched cards. The time required for the execution of any instruction is an integral multiple of the fundamental cycle of the machine which is 12 microseconds. To add takes two cycles or 24μs, to subtract three cycles or 36μs, to multiply 20 cycles or 240μs.

The amount of memory or storage is vast. For this machine a magnetic core can be obtained to store as many as 32,000 words. Additional memory is provided by the addition of tape or magnetic drum which are both slower. The equivalent of 24,000 – 80 column cards can be stored on one tape. The complexity of problem that can be solved is accentuated by the high speed and storage.

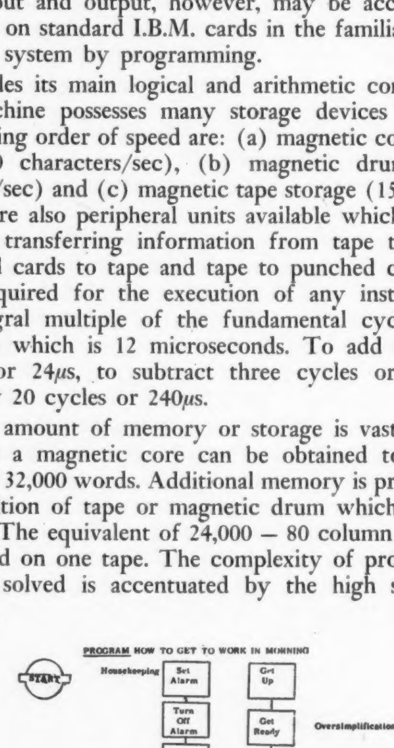

Figure 7

Prior to leaving digital computers, which are so many times referred to as 'electronic brains', it is well to point out that the machines are actually idiots and are still dependent on good programming to maintain their logic. The type of programming needed for a machine is well illustrated by Figure 7.

ANALOG COMPUTERS

Electronic analog computers, similar to their digital brothers, were born during World War II as a means of solving design problems associated with the complex modes of modern warfare. Until recent years, the complete dynamic analysis of a complex system was so uneconomical and time consuming as to make it impossible to handle from the practical point of view. Now, with the tremendous analytical capacity of the analog computer, such problems are brought within the realm of practicability.

An electronic analog computer simulates a physical problem by the substitution of voltages. The voltages are used to represent all the variables. If the relations and parameters are known, computation is a straight forward problem of solving algebraic and differential equations. Electronic analogs are, in general, voltage node devices with all inputs and outputs in the form of voltages.

Briefly the various computing elements associated with the electronic analog computer or, as it is also known, the 'electronic differential analyser' are as follows:

(a) *Reference Supply* is a master voltage source which supplies the computer with all signal voltages. This may be a voltage box which is an adjustable d-c voltage source.

(b) *Coefficient Potentiometer* is a wire wound resistive element with a calibrating sliding contact. The voltage at the sliding contact is the indicated fraction of the voltage applied across the potentiometer.

(c) *The Operational Amplifier* is a high gain d-c voltage amplifier. It may be used for inversion, summation, integration or differentiation. The amplifier is the back bone of the computer. For inversion or sign changing, a resistance is hooked around the amplifier so that in a diagram it looks like Figure 8.

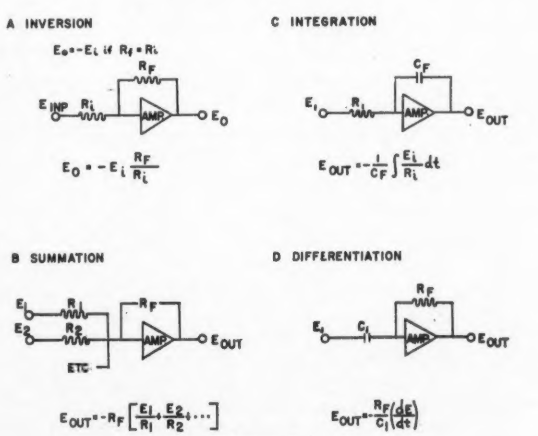

Figure 8

(d) *Multipliers* are devices which provide an output voltage proportional to the product of two variable input voltages so that $E_{out} = E_1 \times E_2$. They can be grouped into servo-multipliers and electronic multipliers.

(e) *Function Generators* are devices supplying an output voltage which is an arbitrary function of the input voltage such that $E_{out} = F(E_{in})$.

These basic components plus resistors, capacitors and plugs form the basic units of the computer. The size of the computer will depend on the amount of amplifiers and potentiometers available. The accuracy will depend on the inherent accuracy of the individual components purchased. For recording of results, either an oscilloscope or Sanborn type recorder may be used.

Principles

Analogies are made possible by nature's system of structural parallelism, in which a physical element in one medium may be represented by a corresponding physical element in another. To best show this, a comparison is made of the direct analogy between the energy in a simple spring mass system and the energy in an electrical capacitor.

Assuming a simple mass supported by a spring and a dashpot with the force acting on it as a function of time, the differential equation for this system is

$$M\ddot{x} + D\dot{x} + Kx = F(t)$$

where $\ddot{x}$ or $\dfrac{d^2x}{dt^2}$ is acceleration $\dot{x}$ or $\dfrac{dx}{dt}$ is velocity and x a linear dimension. The electrical analogy of the capacitor will give the differential equation of

$$L\ddot{q} + R\dot{q} + \frac{1}{c}q = E(t)$$

where L is the inductance, R the resistance, $\dfrac{1}{c}$ the capacitance, E the electromotive force, q coulombs the electric charge, $\dot{q}$ a rate or current and $\ddot{q}$ the acceleration amps/sec. The analogy is best shown in Figure 9.

It is noticed that the various members of the differential equations are analogous; mass is proportional to the inductance, spring is proportional to capacitance, the dashpot is proportional to the resistance and the force is proportional to the electromotive force. The solving of the differential equation for the spring system without the use of automatic calculations involves many tedious days using the iteration method of substituting values for $\dot{x}$, x and $F(t)$ and solving for $\ddot{x}$. Since we can set up an electrical analogy of this equation which behaves exactly as the mechanical system, the problem

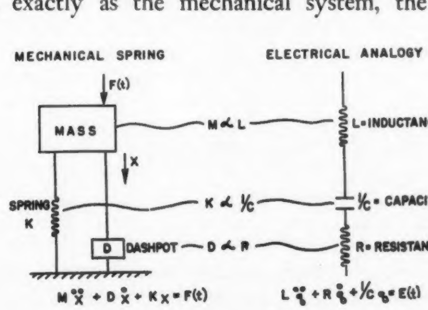

Figure 9

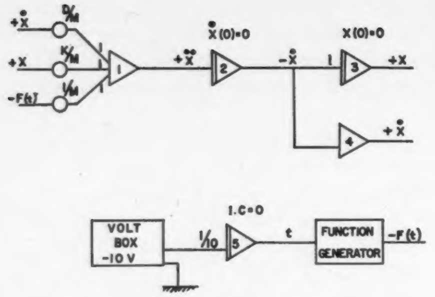

Figure 10

can be solved in seconds, rather than in days, after the wiring has been completed. Figure 10 shows the actual block diagram for the solution of the differential equation

$$M\ddot{x} + D\dot{x} + Kx = F(t) \text{ or } -\ddot{x} = \frac{D}{M}\dot{x} + \frac{K}{M}x - \frac{1}{M}F(t)$$

with initial conditions $\dot{x}\ (o) = 0$: $x\ (o) = 0$.

For clarity, interconnections between terminals on right and left are not shown. The right hand sides are interconnected with their corresponding left hand side to close the loop. The substitution and iteration process is now done automatically. The values of D, K, and M are known. The triangles denote amplifiers, the circles potentiometer, with a scale value of D/M, K/M and $1/M$. The numeral 1 before the amplifier signifies that the input resistors to feedback relationship is one. They are summed through amplifier 1 giving $+\ \ddot{x}$. $\ddot{x}$ is then integrated to give $-\ \dot{x}$ remembering that where we integrate we get an opposite sign. The initial condition of $\dot{x}(o) = 0$ is wired in this amplifier. Integrating again, we get $+\ x$ and again the initial condition of $x(o) = 0$ is wired into the amplifier 3. To obtain $+\ \dot{x}$ we put it through amplifier 4 to change the sign. To generate the voltage $F(t)$, the independent t is obtained by integrating the constant voltage from the volt box. As seen, we started with a -10 volts. We set our feedback to input resistor ratio at 1/10 which gets us back to 1 and the integrating of constant $1dt$ gives us t; this is then put through the function generator which can set up any force time curve, either linear or non-linear, and gives $-\ F(t)$. The variable voltage $\ddot{x}$, $\dot{x}$ and x will be displayed on recording equipment varying with time. The linear combination of these variables can be recorded by means of coefficient potentiometer and summing amplifiers when required.

The electrical voltages in the computer, when wired as shown in the slide, are so constrained as to obey the same mechanical laws of the mechanical system. The behaviour, thus, of the mechanical system can be studied by observing its electrical model. Such parameters as mass, damping coefficient and spring constant, can be altered by changing their scalar value until an optimum design is obtained.

Application

Any problem which involves the solving of differential equations, whether linear or non-linear, is ideally solved on an analog computer. The accuracy of the solution is, of course, dependent upon the accuracy of the installation.

Analog computers are important tools to enable studies of systems where relations describing performance are not clearly known in advance. Portions of systems or complete systems may be simulated by active or passive networks constructed experimentally to give a behaviour approximately known or desired response. All computer representations of real or abstract systems are physical models of extraordinary flexibility. In electronic portions of closed loop control systems and servomechanisms, operational amplifiers can be used as "brains to command the 'muscles' ". The "error" between the ideal or desired condition and the existing condition is constantly measured by an input amplifier and then is amplified, transformed, scaled and applied through power actuators as a corrective force to reduce the error.

Operational circuitry has been profitably used to actually operate simulated plants, processes or machines. Such uses have already enjoyed remarkable success in engine design, autopilot installation in aircraft and missile guidance.

Some typical applications wherein analog computers were used are:

- Chemical Processes
- Automatic Control Design
- Vibration, Stability, Aeroelasticity } Analysis of aeroplanes
- Servomechanisms
- Non-linear Mechanics
- Economics of Power Distribution
- Heat Flow

CONCLUSION

In conclusion, I wish to point out the fact that, under modern development, electronic automatic computing is essential to the engineering field. With the aid of computers, innovations have now been developed which never could have been attempted without them. The rapid advances in nuclear sciences, supersonic flight and guided missiles are strong testimony to their value in analysis, design and development.

It may at the outset appear that analog and digital type machines are competitive, but in reality they complement one another. Each type of problem is more adaptable to one or the other computer. Computations which are too extensive to be undertaken manually and not so elaborate as to justify the use of a high priced digital computer are easily and adequately handled by electronic analog computers. These computers are easy to operate, easy to maintain and service and relatively inexpensive. The parameters, as previously shown, can be changed easily and the time required for setup is short compared with digital computers.

I trust that this short summary may prove of some small assistance in stimulating further study of a field which shows promise of opening the boundless realm of complex computation to the human mind.

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ADHESIVE BONDING OF MAGNESIUM—INCORPORATING A CORROSION RESISTANT HOT ALKALINE CHROMATE TREATMENT AS THE SURFACE PREPARATION†

by R. J. E. Hunter*

Avro Aircraft Limited

INTRODUCTION

IN company with other airplane manufacturers, Avro Aircraft has adopted metal-to-metal adhesives for use in primary parts of the aircraft structure and although no great difficulty has been experienced in the metal bonding of 2024 and 7075 aluminum alloy, a considerable amount of development work was found to be necessary before the metal bonding of magnesium alloys could be brought to the same pitch of perfection.

In the present application of magnesium, a sheet alloy—ZE-41, comprising essentially 4% zinc and 1% cerium (rare earths), in condition H24 and in thicknesses from 0.032″ to 0.080″ — is being used and involves the attachment of doublers, boundary angles, stiffeners and the like. A complication in the bonding process is that protective treatment of the magnesium has to be incorporated as the process cannot be carried out after bonding. One of the reasons for this is that experience has shown metal-to-metal adhesives have very little strength if applied to bare magnesium alloy surfaces, and that pre-treatment of a type similar to that used to obtain a corrosion resistant paint base is necessary.

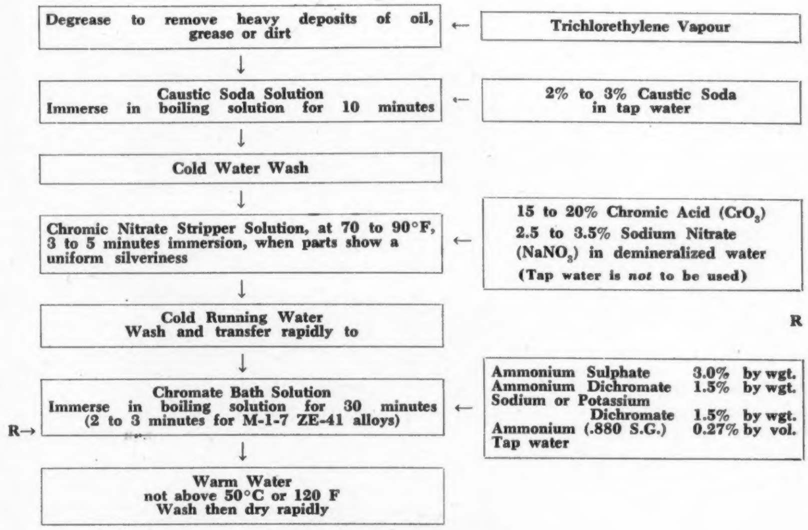

Figure 1
Flow diagram of Avrocan P-1-1 hot alkaline chromate treatment

DEVELOPMENT

Surface preparation

A ceramic type of anodic coating, which was very attractive from an application point of view, provided a very good bonding surface, but its tendency to deep pitting under severe corrosive conditions was considered to be too serious a deterrent for it to be adopted.

The hot alkaline chromate treatment, which has been in standard use at Avro for many years, mainly on castings, and which closely resembles the Dow 8 treatment, whilst giving good corrosion resistance under a standard paint scheme gave very poor results when present at the metal bond interface. The standard 4 finger type of test piece used in MIL-A-5090B had behaved quite well with this protective treatment and the standard bonding cycle and cure used with Narmco 4021 adhesive, but on components having larger bonded surfaces, the peel strength of the bonds was very low, the failure occurring cohesively in the chromate coating; also there was evidence of blistering within the glue line, an indication of trapped volatiles or reaction products.

The hot alkaline chromate treatment used at Avro is covered by Company Specification P-1-1 and is based on British Specification DTD 911; it differs from Dow 8 in that pre-treatment is effected with caustic soda instead of hydrofluoric acid. Figure 1 shows a flow sheet for the process.

The failure of the chromate film was investigated simultaneously along two paths. To overcome the blister-

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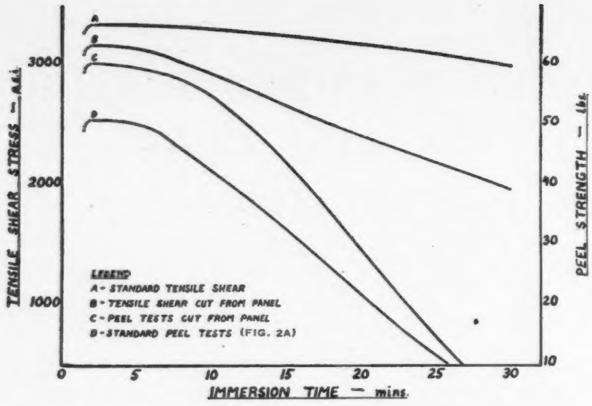

Left—Figure 2
The effect of immersion time in hot chromate bath on the bond strength of ZE-41 magnesium

Right—Figure 2A
Standard peel test

2 minutes

5 minutes

15 minutes

30 minutes

60 minutes

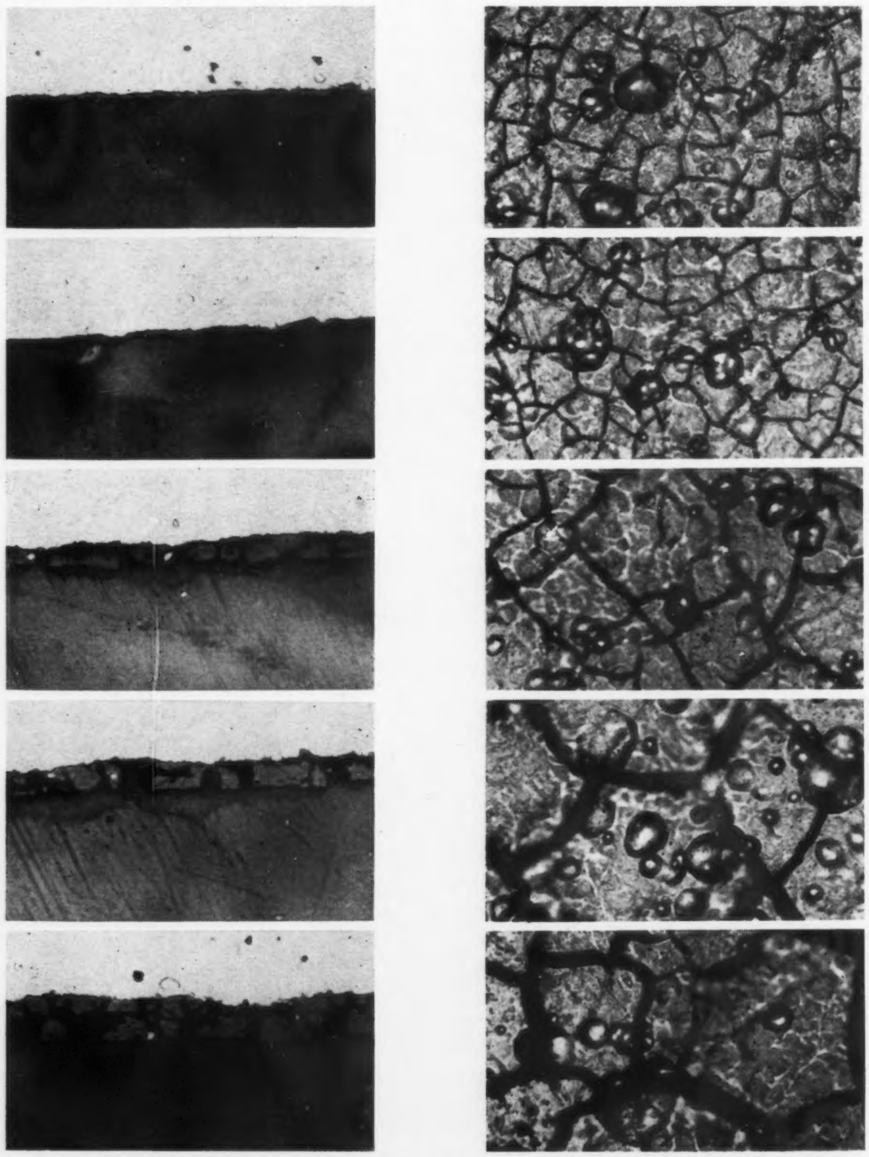

Figure 3
Photo-micrographs of cross sections and surfaces of chromated films produced at varying immersion times

ing caused by the suspected condensation products, a sub-primer was applied to the surface of the chromated magnesium and thoroughly dried before the Metlbond primer was applied over it. Zinc chromate primer to MIL-P-6889 thinned 1:9 with toluol, an epon based clear enamel, regular Metlbond primer diluted for better wetting and penetration were all tried. None of these treatments showed any marked improvement over the normal pre-curing of the Metlbond primer.

In the parallel investigation it was found that satisfactory bonds could be obtained on surfaces pre-treated with the Dow 1 temporary chrome-pickle. Shear values averaged 2,600 psi, and peel strengths were of the order of 40 lb. Subsequent hot alkaline chromate treatment to P-1-1 applied over the bonded specimens did not affect the bond strengths; however, the double treatment would have increased the processing operation and necessitated the provision of additional processing tanks.

Variation of the immersion time in the hot alkaline bath did have a very pronounced effect on the bond strength, both in shear and in tension (peel) Figure 2, and, with times reduced from 30 mins to as low as 2 mins, good bonds were obtained with continuous uniform films. In conjunction with the tests run on the bonding of these reduced time films, a microscope study was carried out on sections through the chromate film – magnesium interface and on the surfaces of the chromate films. Figure 3 shows some of the photo-micrographs.

Examination of these micro-specimens revealed that during the first stage of the treatment a thin light-grey crystalline coating was formed, which was tightly adherent and finely crazed. As the immersion time was continued, these fine cracks were enlarged by the growth of a darker, amorphous material, which forced small fragments of the original coating to the outer surface. After the full 30 minutes, the coating had the appearance of a rough conglomerate of minute grey slabs imbedded in the softer dark material. With ZE-41, this light grey coating was formed in the first five minutes of the treatment.

Corrosion tests carried out in the standard QQ-M-151, 20% sodium chloride salt spray cabinet on chromate treated and primed (MIL-P-6889) panels showed equally good corrosion resistance for coatings applied in 2, 5 or 30 minutes.

Curing

As the appearance of the glue line even in the best of the bonds under the previous cures was of a somewhat porous nature, as though some volatiles were being trapped, a further refinement of the curing cycle was necessary. Varying temperatures and times from ¾ hours at 350°F to 1½ hours at 300°F did not seem to improve this condition. Not until a deliberate attempt was made to allow the condensation products to escape during the initial curing was an improvement made. This was accomplished by applying only vacuum pressure to the curing components, until the temperature reached 250°F and holding at that temperature for a short time, then increasing the pressure and temperature to complete the cure. With this approach the strength for tensile and peel specimens cut from panels were 3,000 psi, and 50 lb; the failure was cohesive within the glue line and no longer had the porous nature. Further work on this curing cycle revealed that the time required to reach the

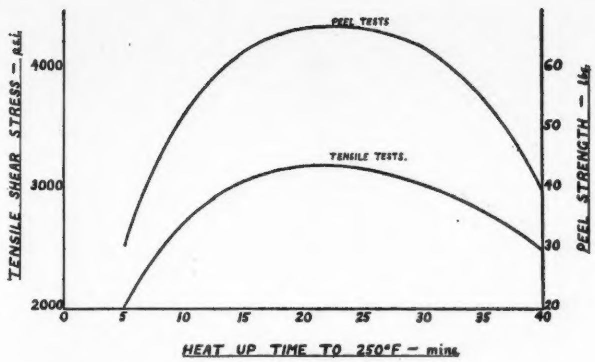

Figure 4
The effect of heat up time to 250°F on the bond strength of ZE-41 magnesium

250°F temperature was very important. Too fast a heat-up time did not allow the volatiles to escape and with a prolonged heat-up a partial cure was effected before the final pressure was applied and an excessively heavy glue line was obtained (Figure 4). The optimum time was found to be between 15 and 30 minutes, to reach a temperature of 250°F. With this finalized curing cycle the effect of the pH in the hot chromating tank on the resultant bond strengths was determined. A pH of from 5.7 to 5.9 was found to give consistent good bonds (Figure 5).

Complete process

The complete process for bonding ZE-41 magnesium as developed is as follows:

(1) *Surface Treatment Prior to Bonding*
Chromate to Avrocan Process Specification P-1-1 immersion time in chromating tank 2 to 3 minutes – pH of chromating tank 5.7 to 5.9.

(2) *Priming of Chromated Magnesium*
- (a) Brush a thin uniform coating of Metlbond 4021 Type 11 primer – allow to air dry for 20 minutes.
- (b) Bake in air circulating oven at 300°F for 10 minutes.
- (c) Brush a second uniform thin coating of Metlbond 4021 Type II primer – allow to air dry for 20 minutes.
- (d) Pre-cure primed magnesium in air circulating oven at 300°F for 1 hour.

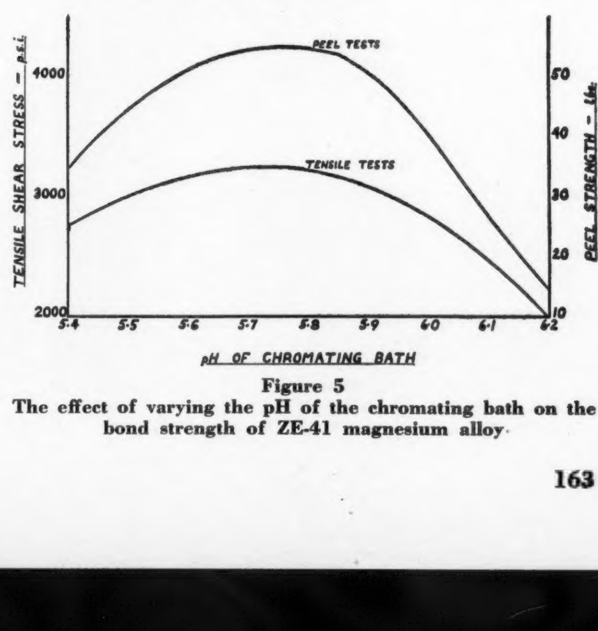

Figure 5
The effect of varying the pH of the chromating bath on the bond strength of ZE-41 magnesium alloy

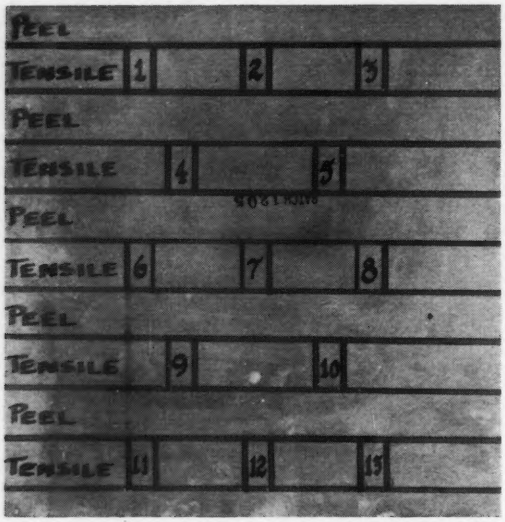

Figure 6
12" x 12" bonded panel showing positions of test coupons

(3) *Curing Cycle* (*Autoclave Method*)

(a) With vacuum pressure only on the assembled components (Metlbond 4021 film in position between the primed surfaces) raise the temperature to 250 $\pm$ 10°F and hold for 10 minutes. Time to reach this temperature must not exceed 30 minutes, not be less than 15 minutes from commencing heating.

(b) Increase pressure to 100 $\pm$ 20 psi.

(c) Raise temperature to 300°F.

(d) Hold at 300°F for 1½ hours.

(e) With pressure at 100 $\pm$ 20 psi, reduce temperature to 140°F.

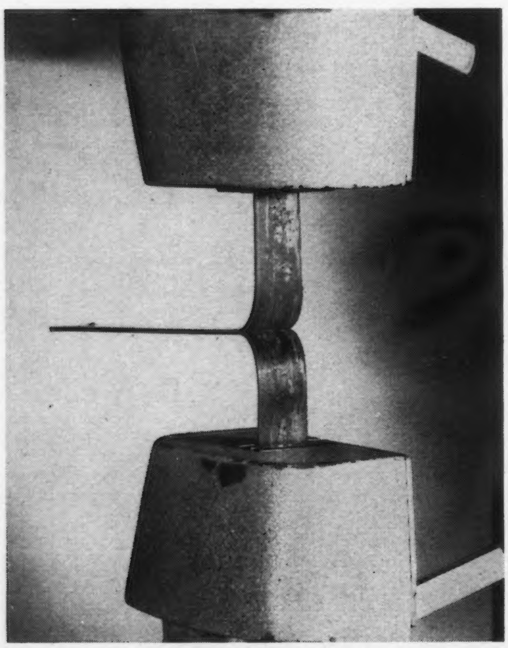

Figure 7
Avro modified peel test

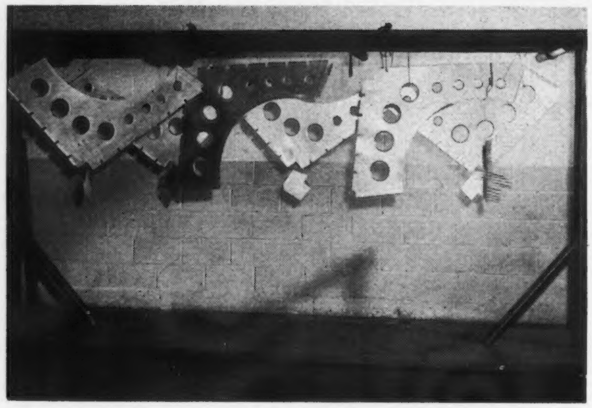

Figure 8
Processing rack with components in position on truck

(f) Release pressure and remove bonded components.

(4) *Inspection*

(a) With every batch of magnesium components two 1 ft square panels (Figure 6) are included. These must follow the process through from initial cleaning, chromating, priming to curing.

(b) This bonded panel is cut into 1" wide strips to be tested alternately as peel and tensile specimens.

(c) Tensile strength must average 2,000 psi with no value less than 1,500 psi.

(d) Peel strength when the two halves are pulled apart at 180° to each other at 3½ inches per minute must not be less than 40 lb (Figure 7).

DESCRIPTION OF AVRO METAL BONDING PROCESS FOR MAGNESIUM

After the to-be-bonded components have had a trial assembly to insure that all dimensions are correct and that the mutual conformity of curvatures is such that a good fit can be obtained at the adhesive line with no more than light finger pressure, they are suspended with appropriate test coupons from a rack on a truck (Figure

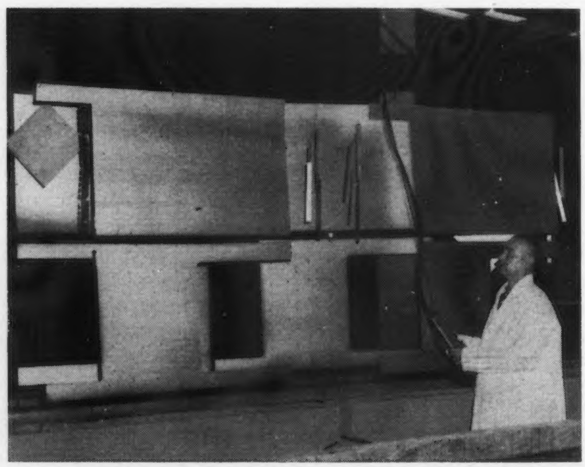

Figure 9
Components suspended from processing rack receiving chemical surface treatment

8). The truck is moved to the cleaning area where the rack with components is vapour degreased with trichlorethylene. The aluminum components are etched in the standard sulphuric acid, sodium dichromate solution for 5 to 7 minutes, bath temperature at 150° ± 10°F. After etching they are well rinsed with water and inspected for a no-water break surface. Clean dry air is then used to blow off the excess water and dry them.

With magnesium after degreasing they receive the 2-3 minute hot alkaline chromate treatment. All components remain on the racks (Figure 9) during the surface treatment prior to priming. They are then taken to the bonding shop where they receive the priming coat within one hour. The operators handling the components from the racks during priming and film lay up wear clean white cotton gloves. The adhesive film is tailored to fit the components and a few Cherry rivets are used to insure no movement of the components during bonding. The assembled components are wrapped in canvas and inserted into a polyvinyl alcohol bag fitted with felt as a vacuum bleeder. This bagging operation is carried out on the large autoclave tray, which later is rolled into the autoclave (Figure 10). Four autoclave batches per day are possible.

In Table 1 are shown some typical inspection results of shear and tension (peel) tests obtained on the 4 finger type specimens of MIL-A-5090, and on specimens cut from 12″ × 12″ panels, bonded with acutal components. Figures obtained with 24S aluminum alloy are included for comparison purposes.

TABLE 1

	Batch No.	Mil-A-5090 B Tensile(1)	Panel (Avro Test)	
			Tensile(2)	Peel(3)
Magnesium ZE-41 alloy	1205	3690 psi	2560 psi	55 lb
	1209	3190 psi	3020 psi	75 lb
	1210	2980 psi	3495 psi	65 lb
	1211	3145 psi	3220 psi	75 lb
24S Aluminum alloy	1198	4540 psi	4220 psi	80 lb
	1200	4400 psi	4155 psi	83 lb
	1201	4720 psi	4305 psi	87 lb
	1202	4430 psi	4490 psi	80 lb

(1) Average of 15 tests.
(2) Average of 8 tests.
(3) Average of 5 tests.

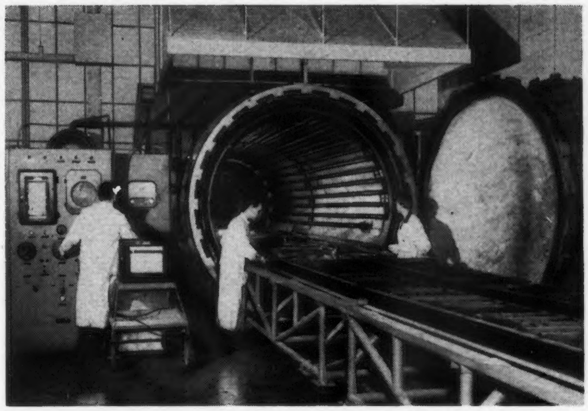

Figure 10
Production autoclave

Results of magnesium bonding procedure tested according to MIL-A-5090B, adhesive, airframe structural, metal-to-metal are given in Table 2. ZE-41 magnesium alloy was used for the standard test specimens and for the panels .057″ sheet stock was used.

TABLE 2

Test No.	Condition and Type of Test	No. of Specimens Tested	Minimum Strength Requirements	Standard Test Specimen	Specimen Cut From Panel
1	Standard Temp. Shear Strength	10 10	2500 psi	3260 psi	3080 psi
2	250°—Shear Strength	10 8	1250 psi (at 180°F)	1515 psi	1600 psi
3	−67° ±2°F Shear Strength	5 5	2500 psi	3150 psi	3230 psi
4	Standard Temp. Fatigue Strength	6 4	600 psi	900 psi	800 psi
5	Standard Temp. Creep-rupture strength and deformation for 200 hours	3 3	1600 psi 0.015 in max total deformation	1800 psi	1750 psi
6	250 ± 2°F creep-rupture and deformation for 200 hrs.	3	800 psi (at 180°F) 0.015 in max total deformation.	*	*
7	Standard Temperature Bend Strength	5 8	150 lb min load	190 lb	167 lb
8	250° ± 2°F bend strength	5		148 lb	

*The shear strength of the bond was stronger than the tensile creep strength of the metal at 250°F. Heavier gauge material would be necessary to determine the creep rupture at this temperature.

CANADIAN AERONAUTICAL INSTITUTE
EDUCATION & TRAINING PROGRAMME

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RESPONSIBILITY OF MEMBERS

EVERYONE in the Aviation Industry is aware of the shortage of engineering personnel at all levels; and that this is having a serious effect on the rate of production.

Two very important factors affect this shortage:

1) As high as 24% of students drop out of High Schools at the age of sixteen to go into industry to make easy money for unskilled work. A large percentage of these students have the mental ability to finish High School at Matriculation level.

2) Up to 30% of University Engineering students fail in their first year. Almost invariably, this failure is due to inability to work steadily at their studies.

Governments and industrial firms can furnish funds to provide buildings and instructional staff; but obtaining the additional engineering personnel is a matter for continued personal effort of individuals. The C.A.I. members can have great influence in this matter. The following are suggestions for action:

1) Make yourself familiar with the requirements for entrance into Engineering Colleges and Technology Institutes so as to be able to advise young people what to study.

2) Encourage students of all ages to develop a habit of work with their studies.

3) Stimulate the imagination of students about the Engineering Professions whenever possible.

4) Take an interest in Home and School meetings. Look into what is being done to encourage students to work toward engineering and scientific careers.

5) Encourage people in your plant to up-grade their engineering knowledge by study through existing channels and even to go back to school if possible.

Your Provincial Education and Training Committee will be glad to advise you on any problems you may have.

C.A.I. LOG

SECRETARY'S LETTER

KINGSTON

ON the 4th April, I visited the R.M.C. Kingston to discuss the possibilities of forming a Student Section there. S/L Evans of the staff had arranged for about 65 Cadets to come together for a short meeting; I said a few words to them and they fired a lot of questions back at me. In the end they set to, there and then, and elected an Interim Committee, whose job it will be to get something organized and perhaps hold a meeting or two before they all go their several ways for the summer. Then we shall have a foundation to build on in the fall.

If this Section can be established, it will operate under the general guidance of the Ottawa Branch.

HALIFAX-DARTMOUTH

The first Annual General Meeting of the Halifax-Dartmouth Branch was held on the 24th April and I managed to attend this historic event. The Interim Executive Committee has done well in getting the Branch going; since its formation in November, it has held half a season of monthly meetings and conducted its election in accordance with our normally established practices.

In my visits to various Branches, it is very interesting to see how each develops its own variation on our common theme. The Halifax-Dartmouth Branch is, of course, predominantly naval. The majority of its members are either employed by Fairey Aviation or in the R.C.N. at H.M.C.S. Shearwater. Although superficially their meeting resembled meetings at other Branches, I think that anyone who has ever dabbled in salt-water aeronautics would have sensed the difference.

I was met by Commander Morris and CPO Sabourin who, with Commander Neil Smith, took me on a tour of H.M.C.S. Shearwater before handing me over to Mr. Wallworth of Fairey Aviation. Mr. Wallworth showed me around the Fairey plant and I regret to say that we wasted a lot of his time remembering, perhaps with some advantage, some of our mutual acquaintances of the '30's. (I wonder if *we* seemed so incredibly funny to them . . .)

Later I was taken to dinner and the meeting by Mr. Garrard, the Chairman of the Branch. It was not all business, for we had a most interesting talk by Mr. Eames of the Naval Research Establishment on hydrofoil boats – an unusual subject for an aeronautical audience but sufficiently kindred to be of fascinating interest.

The Halifax-Dartmouth Branch is so situated geographically that I think they are a little concerned about the supply of speakers for their meetings. I earnestly ask all our members to bear their needs in mind. If any of us hears of a likely speaker visiting that part of the world, we should let the Branch know about him as far in advance as possible. Don't leave everything to the Programmes Committee; we are all in this thing to help one another and some of our smaller Branches depend on our help.

REGRADING

Several members, in paying their dues for 1957-58, have asked what steps they should take to apply for advancement in grade and some have even gone to the trouble of setting out, in their letters, all their more recent qualifications. Of course, in this day and age, there is a form to be filled up. When someone has already told his story fairly fully, it may seem rather an imposition to ask him to do it all over again on a form, but believe me, the forms are necessary if we are to do things in an orderly manner.

These forms can be obtained locally from Branch Secretaries or from this Headquarters.

VOL. 2, NO. 3, MARCH 1956

We receive a number of requests, from libraries and the like, for back numbers of the Journal. So far we have always been able to meet them but we are now completely out of copies of the issue of March 1956. We should be very grateful if any members, having copies of this issue which they do not want, would return them to this Headquarters rather than throw them away.

ANNUAL GENERAL MEETING

Programme

May 27th Morning 9.00 a.m.

BUSINESS MEETING

President
T. E. Stephenson
Sales Engineering and Service Manager,
Canadian Pratt & Whitney Aircraft Company Ltd.

Annual Reports of the Council and of the various Committees

May 27th Morning 10.45 a.m.

DESIGN AND STRUCTURES

Chairman
R. E. Klein
Chief Stress Engineer, De Havilland Aircraft of Canada Ltd.

Structural Testing the RCAF Argus
C. A. Bloom
Section Chief, Structural Test, Canadair Ltd.

The Application of Ultra High Tensile Steel to the Design of a Modern Undercarriage
G. F. W. McCaffrey
Chief Engineer, Dowty Equipment of Canada Ltd.

May 27th Afternoon 2.00 p.m.

TEST PILOTS SECTION

Chairman
W. S. Longhurst
Chief of Flight Operations, Canadair Ltd.

Business Session

The Test Pilot and the Flight Test Engineer
S/L O. B. Philp
Formerly Chief Test Pilot, Central Experimental & Proving Establishment

F/L K. D. J. Owen
RCAF Flight Test Engineer,
No. 12 Technical Services Detachment,
Avro Aircraft Ltd.

MATERIALS

Chairman
S/L W. G. Chandler
Commanding Officer, Quality Control Laboratory
RCAF Station Victoria Island, Ottawa

The Application of Non-metallic Materials to Gas Turbine Engines
J. A. Fortune
Metallurgist, Orenda Engines Ltd.

High Strength Nickel-Chromium Alloys for Elevated Temperature Service
K. B. Young
Metallurgical Engineer, Development and Research Division,
The International Nickel Company of Canada Ltd.

Trends in Lubrication
R. O. Campbell
Chief Chemist
S. C. M. Ambler
National Supervisor, Industrial and Transportation,
The British American Oil Company Ltd.

DINNER

7.00 p.m. **Ballroom**

Chairman
T. E. Stephenson
President, Canadian Aeronautical Institute

Principal Speaker
E. T. Jones
Director General of Technical Development (Air),
Ministry of Supply
President 1956-57, Royal Aeronautical Society

Presentation of the McCurdy Award
and the
F. W. (Casey) Baldwin Award for 1956

May 28th Morning 9.00 a.m.

NOISE

Chairman
WINNETT BOYD
President, Winnett Boyd Limited

Noise Research in the United Kingdom
PROFESSOR E. J. RICHARDS
Professor of Aeronautical Engineering,
University of Southampton

Noise – Some Implications for Aviation
DR. K. K. NEELY
Chief, Sonics Section, Psychology and Sociology Wing,
Defence Research Medical Laboratories

ANTIICING AND DEICING

Chairman
J. H. PARKIN
Mechanical Engineering Division, National Research Council

Some Aspects of Helicopter Icing
J. R. STALLABRASS
Assistant Research Officer, Low Temperature Laboratory,
National Research Council

Aircraft Gas Turbine Ice Prevention: The Design and Development of Hot Air Surface Heating Systems
D. QUAN
Supervisor, Systems Analysis, Orenda Engines Ltd.

C. K. RUSH
Associate Research Engineer, Low Temperature Laboratory,
National Research Council

Ice Crystals: A New Icing Hazard
O. R. BALLARD
(D. Napier & Sons Ltd.) Icing Representative,
Ministry of Supply

B. QUAN
Assistant Research Officer, Engine Laboratory, National Research Council

May 28th Afternoon 2.00 p.m.

AVIATION MEDICINE AND HUMAN ENGINEERING

Chairman
A/C A. A. G. CORBET
Director General Medical Services Air,
Royal Canadian Air Force

Introduction of Human Engineering
R. E. F. LEWIS
Human Factors Engineer, Avro Aircraft Ltd.

Safety First and Always
J. A. GILLIES
Chief Engineer

R. J. BURDEN
Assistant Chief Engineer

K. E. MARSDEN
Chief Inspector
Canadian Pacific Air Lines Ltd.

Specific Aeromedical Problems in High Performance Aircraft
S/L R. A. STUBBS
Medical Associate/Biophysicist,
RCAF Institute of Aviation Medicine

AERODYNAMICS

Supercirculation – An informal discussion

Moderator
R. J. TEMPLIN
Head, Aerodynamics Section, National Research Council

DR. G. W. JOHNSTON
Special Project Engineer, De Havilland Aircraft of Canada Ltd.

H. C. EATOCK
Supervisor of Aerodynamics, Orenda Engines Ltd.

S. J. POPE
Chief Aerodynamicist, Canadair Ltd.

Preprints of the papers to be presented at the meeting will be on sale at the registration desk at the meeting.

Dinner tickets. It is desirable that tickets for the dinner should be purchased in advance to assist the planning and arrangements. However, dinner tickets will be procurable at the registration desk and at the entrance to the Ballroom until the time of the dinner. Attention is particularly directed to the fact that no refunds on dinner tickets will be made after 4 pm on the 27th May.

MEETINGS

ANNUAL GENERAL MEETING

Notices giving the full programme of the Annual General Meeting have been sent to all members of the Institute; the programme is also set out on the preceding two pages.

ABSTRACTS

The following are abstracts of some of the papers to be presented at the Annual General Meeting.

Structural Testing the R.C.A.F. Argus

C. A. Bloom – Canadair

The importance of structural testing in the design of a new aircraft is reviewed. Though the Bristol Britannia airframe on which the RCAF Argus is based has been tested exhaustively, a number of important structural differences between the two aircraft resulted in further extensive testing for the Argus.

The entire programme consisted of static and fatigue tests in three main categories: Americanization, sub-assemblies and special parts, and complete components.

Tests in the first two categories, now completed, are summarized briefly. The third category involves only the fuselage structure and fin. A full description of the static tests, techniques and equipment employed is presented. To date, the fuselage has withstood successfully all critical limit loads and the remainder of the programme is proceeding.

The Application of Ultra High Tensile Steel to the Design of a Modern Undercarriage

G. F. W. McCaffrey – Dowty

During the past two and one-half years, the author's company has been engaged in a program which is believed to be unique in this country, that is, the design and manufacture of a major structure in steel having an ultimate tensile strength of 270,000 psi.

The paper begins with a brief description of the undercarriage. This is followed by a more detailed discussion of the problems resulting from the use of this material under the headings: specification and procurement of the steel, manufacturing and processing, heat treatment, plating, mechanical properties and testing.

The text is supplemented by a series of slides covering various phases of the program.

The Test Pilot and the Flight Test Engineer

S/L O. B. Philp and
F/L K. D. J. Owen – R.C.A.F.

This paper describes the authors' personal opinions on the work of the test pilot and the flight test engineer. The qualifications and experience needed by those who engage in flight testing, both test pilot and engineer, are discussed and the relationship that should exist between these two specialists in their work is described at length.

The Application of Non-Metallic Materials to Gas Turbine Engines

J. A. Fortune – Orenda

The ever increasing demands on present day materials for the modern gas turbine has led to a concentrated search for better high temperature properties of organic and inorganic materials.

The requirements on reinforced plastics have been increased to 1,500°F, on elastomers up to 600°F, on lubricating and hydraulic oils to 700°F and on insulating materials to 3,000°F. This paper deals with the high temperature uses of non-metallic materials pointing out the need for more specific design data so that a further extension of these materials may be realized.

High Strength Nickel-Chromium Alloys for Elevated Temperature Service

K. B. Young – International Nickel

During the past fifteen years, complex nickel-chromium alloys have been widely used in aircraft gas turbines for highly stressed components in the temperature range of 1,000° to 1,600°F. The salient characteristics of this group of materials are reviewed and in particular the influence of heat treatment is shown to have a marked effect on the creep and fatigue properties of a nickel-chromium-cobalt base forging alloy.

Reference is made to some of the more recent metallurgical developments including a cast nickel-chromium base alloy which has exceptional creep-rupture properties at temperatures up to 1,750°F, some 100°F higher than the best commercially available wrought materials.

Trends in Lubrication

R. O. Campbell and
S. C. M. Ambler – British American Oil

Friction is defined as the "resistance of one surface to the motion of another surface rubbing over it". With thick film liquid lubrication the surfaces are completely separated by the lubricant and there is no wear. There is less friction and heat developed with thick film lubrication because the metal shearing is replaced by oil shearing. Research has resulted in improved temperature tolerance of petroleum lubricating oils. Chemical additives have been developed that further improve the ability of oils to perform their specific functions.

Presently developed petroleum oils have satisfactorily lubricated aircraft piston engines. The trend toward higher roller bearing temperatures in the newer aircraft gas turbine engines has, in instances, exceeded the temperature tolerance of refined petroleum oils. Recent formulations of synthetic oil bases plus chemical additives have greater temperature tolerances and are being used extensively in the newer gas turbine engines.

Experimental work on the use of air-blown mists of solid lubricants have indicated promise of roller bearing operation at temperatures higher than those possible with liquid lubricants.

Noise Research in the United Kingdom

Professor E. J. Richards – University of Southampton

Unlike other aeronautical research in the United Kingdom, jet noise and propeller noise research is mainly confined to the Universities and engine firms. This paper outlines the present situation both in fundamental research and in the more ad hoc work of the firms.

A description is given of work aimed at fundamental understanding of the production of noise from jets and propellers and of the effects of pressure ratios and nozzle design. Methods of noise suppression are outlined. A description is also given of the work now proceeding on the allied boundary noise problem.

In addition to its effect on personnel on the ground, the noise problem has now begun to present serious difficulties in its effect on structural fatigue. Work on correlation techniques, on the general problem of structural damping and on the response of structures is also described.

Noise – Some Implications for Aviation

Dr. K. K. Neely – D.R.M.L.

Noise has become one of the important problems in aviation. Its effects on hearing, voice communications and man's ability to perform certain tasks are becoming more and more pronounced.

Criteria and regulations for the protection of personnel from high intensity noise have to be initiated and implemented. Similarly criteria and procedures have to be formulated and used to minimize the decrease in efficiency with which man can communicate and work in high intensity noise areas.

Suggestions are outlined that will aid the airport operators to attenuate and control high intensity noise which may result in an increase in the efficiency of airport operations.

Some Aspects of Helicopter Icing

J. R. Stallabrass – N.R.C.

This paper opens by outlining how the icing problem for helicopters differs from that for conventional fixed wing aircraft and how the National Research Council approached this problem. The special spray rig, constructed for the in-flight study of the phenomenon and for the testing of protective systems, is described. The effects of rotor blade icing on the performance and handling of the helicopter are discussed together with special design considerations due to icing on items other than primary lifting surfaces. Methods of protection are reviewed, with particular emphasis on electrical methods.

Aircraft Gas Turbine Ice Prevention: The Design and Development of Hot Air Surface Heating Systems

C. K. Rush – N.R.C.
and D. Quan – Orenda

The problem of protecting an aircraft gas turbine engine from the hazards of icing is presented from a designer's point of view. The basic objective is a system having minimum weight and performance penalties together with maximum duration of protection and reliability. Consideration of the various available protective methods points to the hot air surface heated system as a satisfactory compromise, provided a control system is used to prevent the waste of hot air. The design of such a system is then considered and it is pointed out that the many assumptions which are made lead to the necessity of development tests so that the design may be proved and refined. The advantages of the use of icing tunnels for component and assembly testing and development are discussed.

Ice Crystals: A New Icing Hazard

O. R. Ballard – Napier
and B. Quan – N.R.C.

Recent flight experience in ice crystal clouds has focused attention on an icing problem previously ignored.

The nature of these clouds and the effect of crystal ice formation on anti-icing systems designed for supercooled droplet icing are considered.

Various methods of simulating icing conditions are reviewed and the methods used at the National Research Council of Canada for full scale gas turbine tests are described.

The importance of ice detection systems which distinguish between supercooled and ice crystal clouds is pointed out.

More extensive meteorological data concerning the occurrence of ice crystal and mixed clouds is required to predict the likely frequency of encounters. The severity of the problem can then be assessed in the light of this further data.

Introduction of Human Engineering

R. E. F. Lewis – Avro

The paper describes the origin, nature and application of Human Engineering in an introduction of the subject to those people concerned with aviation in Canada.

Some basic Human Engineering considerations in the design and development of aircraft are discussed together with examples of the research that must support many of the recommendations made by the human engineer in practice.

Specific Aeromedical Problems in High Performance Aircraft

S/L R.A. Stubbs – RCAF Institute of Aviation Medicine

The aeromedical problems which arise within the flight envelope of a hypothetical high performance aircraft are presented.

The effects of the reduction of total pressure and oxygen partial pressure are discussed. The requirements for a pressure cabin during normal flight and for personal pressure garments in the event of cabin pressure loss are established in relation to the operational role of the aircraft.

The problems of escape are presented from the viewpoint of human tolerance to the initial ejection acceleration, windblast pressure and deceleration.

Current practice and achievement as well as future development trends are discussed.

BRANCHES

AMHERST

Some interest has been shown in the formation of a Branch at Amherst, N.S. Such a Branch would probably cover Moncton, N.B., which is not far from Amherst and where there are already a few members of the Institute.

Mr. D. A. Sanford of Enamel & Heating Products Ltd. has kindly offered to serve as Interim Secretary. He will hold a small stock of application forms and literature about the Institute and will keep in touch with Headquarters on matters relating to the development of the Branch.

Mr. Sanford's address is:

15 Westminster Avenue,
Amherst, N.S.

and any enquiries about local activities of the C.A.I. should be referred to him.

NEWS

Montreal

Reported by W/C C. R. Thompson

March Meeting

"The Problems of Jet Transport Operation" was the subject of the talk by Mr. J. T. Dyment, Chief Engineer for Trans-Canada Air Lines, given at the March meeting of the Montreal Branch, C.A.I.

The paper dealt with some of the main difficulties to be overcome before mass air transportation by jet aircraft is a reality. Mr. Dyment said that by 1961 T.C.A. will have an all-turbine-powered fleet. To handle this fleet efficiently will require improved methods of handling passengers, air freight and accounting, including reservations.

The speaker was introduced by the Montreal Branch Chairman, Mr. T. A. Harvie, and was thanked by Mr. R. D. Richmond. An interesting question period after the talk elicited the following information.

Fares will not necessarily increase with the introduction of the new jet aircraft because if they are operated at a fairly high utilization they will be less expensive to operate. However, due to the continual rising spiral of increases in costs of everything, rates may be increased by the time these aircraft go into service.

It is expected that ground facilities will be available by 1960 when the big jets will be in operation. The Department of Transport has promised to have the facilities available. In some areas it does not look as if there is enough time left but everyone is still planning to be ready.

The final configuration of the Dorval airport building has not been decided. There is still some controversy as to whether the finger-type of layout is acceptable.

Only five per cent of the international airports of the world will handle sufficient traffic to make it necessary for the large jets to operate into those airports.

T.C.A. will be unable to handle both the old type and new jet type aircraft and must retire the older type aircraft as the new ones are received.

On a question as to the future of the Winnipeg airport, the answer was given that Winnipeg is considered a vital part of the T.C.A. airline and will continue to be developed.

Cold Lake

Reported by R. W. Ellard

March Meeting

The March meeting of the Cold Lake Branch took place at 8.30 pm on Thursday, March 21st, in the library of the Sergeants Mess. Mr. C. I. Soucy of AMCHQ, Ottawa, was the guest speaker.

Mr. Soucy was introduced by the Branch Chairman, S/L R. G. Christie, and spoke on "Management aspects of reliability control of aircraft and weapons systems electronics". Since Mr. Soucy has previously given this same talk to the Ottawa and Edmonton Branches, no summary is included in this report.

W/C R. D. H. Ellis thanked the speaker and a question period followed. Refreshments were served during the question period.

Twenty-seven members and guests attended this meeting.

Vancouver

Reported by R. W. Van Horne

April Meeting

The April meeting of the Vancouver Branch of the C.A.I. was held on April 15th, 1957, at the Officers' Mess, 1021 West Hastings Street, and was attended by approximately 75 members and guests.

The honored guests, Mr. F. Ellis, author of "Canada's Flying Heritage", and McKee Trophy winners, Mr. G. W. G. McConachie, Mr. M. Burbidge and Mr. T. W. Siers, were entertained at a pre-meeting dinner by members of the Branch Executive.

Chairman Mr. H. H. Ollis opened the meeting and welcomed our distinguished guest speaker, Mr. Frank Ellis, who is one of Canada's early flyers. Mr. Ellis traced the earliest days of aviation in Canada by showing several photos with the aid of a reflectoscope. Among the photos shown were Mr. Baldwin's "Redwing", which first flew in March, 1908; Mr. McCurdy's "Silver Dart", which was the first to fly in Canada in February, 1909; and the first Canadian-developed aircraft engine developed by Mr. Gibson in 1908. Shown also were photos of the first seaplane to fly in Canada, which was at Vancouver in 1914; and the first parachutist, Mr. Seymour, in 1912.

Mr. Ellis traced the first cross-Canada flight of 1920 with photos of some of the letters carried on that historic occasion.

The guest speaker then reviewed the life of Mr. Dalzell McKee whose interest in the furtherance of Canadian aviation prompted him to establish the McKee Trophy for meritorious service in the development of aviation in Canada. It it unfortunate that Mr. McKee did not live to see his trophy awarded.

Mr. Ellis then introduced Mr. Burbidge, Mr. Siers and Mr. McConachie, who each related one of the more amusing incidents in their respective aviation careers.

Our guests were warmly thanked by Mr. I. A. Gray, Past Chairman, for a most informative and entertaining evening.

The meeting came to a close at 11 pm.

MEMBERS

NEWS

Dr. E. P. Warner, Hon. F.C.A.I., is retiring on the 18th April as President of I.C.A.O. and returning to the U.S.A. to take up residence there.

A/V/M A. L. James, F.C.A.I., has been appointed President of Bristol Aero Engines Ltd. and Bristol Aero Engines (Western) Ltd.

Dr. D. C. MacPhail, F.C.A.I., has been appointed Director of the N.R.C.'s Division of Mechanical Engineering, succeeding J. H. Parkin who has retired.

A/V/M C. A. Cook, A.F.C.A.I., was recently appointed Air Officer Commanding, RCAF Air Materiel Command HQ, Rockcliffe.

Professor D. L. Mordell, A.F.C.A.I., was named Dean of the Faculty of Engineering at McGill University, effective June 1st.

H. B. Picken, A.F.C.A.I., has been appointed Vice-President Engineering of the newly-formed Rotaire Ltd., Malton.

E. J. Carr, M.C.A.I., recently resigned from Avro Aircraft Limited to join Convair, San Diego, as a Design Engineer.

F. M. Figueroa, M.C.A.I., formerly with Canadair Limited, has taken up a post with Republic Aviation Corp., Farmingdale, as Specialist Thermodynamics Engineer.

W/C W. J. Grant, M.C.A.I., has recently taken over command of No. 11 Technical Services Unit in Montreal.

W. S. Haggett, M.C.A.I., has been appointed President and Chief Executive of The Bristol Aeroplane Company (USA) Inc., to be formed in New York City.

D. E. Hastwell, M.C.A.I., Technical Representative with Canadair Limited, has been posted to Brescia, Italy.

A. R. Limmert, M.C.A.I., has been appointed Vice-President and Managing Director of the newly-formed Rotaire Ltd., Malton.

W/C R. A. Skuce, M.C.A.I., has assumed the duties of Senior Technical Services Officer at AMC/HQ, RCAF Station Rockcliffe.

G. R. Wooll, M.C.A.I., has been appointed President of the newly-formed Rotaire Ltd., Malton.

Cdr. H. J. Hunter, Associate, was recently privileged to lead the first RCN Trans-Atlantic flight. Experimental TEN Detachment, proceeding to the United Kingdom for flight trials on HMCS Bonaventure, flew over in company with RCAF aircraft.

LCDR J. J. MacBrien, Associate, has left the Royal Canadian Navy to take up a post with Canadair Limited in the Development Engineering Dept.

D. G. McCrae, Technical Member, formerly with Trans-Canada Air Lines, has taken up a position with Standard Aero Engines Ltd. as Service Engineer.

R. Malet de Carteret, Technician, presently employed by Canadair Limited, has been awarded an Athlone Fellowship.

OBITUARY

It is with great regret that we note the passing of Air Vice Marshal Ernest Walter Stedman whose life has been an inspiration to many, particularly in the aviation world.

Born at Malling, England, in 1888, A/V/M Stedman received his education through the Royal College of Science, London, as a Whitworth scholar; one of the highest awards of his time.

After serving his apprenticeship in industry, he was appointed in 1914 as Senior Assistant in Aeronautics at the National Physics Laboratory, Teddington. On the outbreak of World War I, he joined the Royal Naval Volunteer Reserve, transferring later to the Royal Naval Air Service.

While serving with the Royal Naval Air Service, he was stationed at Coudekirk near Dunkirk with the squadron of biplane Handley Page bombers which were the largest in the world of those days. In April 1918, he was posted to the newly formed Royal Air Force, being finally promoted to the rank of Lieutenant Colonel.

At the end of the war, Lt. Col. Stedman joined the Handley Page Company as head of the technical staff. When Vice Admiral Kerr, in June 1919, decided to try the Atlantic crossing for the Daily Mail £10,000 prize, using a Handley Page aircraft, Lt. Col. Stedman was sent to Newfoundland as technical adviser. The flight did not take place as Alcock and Brown made the crossing first in a Vickers aircraft; but this whole story has been recorded by A/V/M Stedman in his memoirs.

In 1920, Lt. Col. Stedman moved to Canada to become Chief of the Technical Directorate of the Air Board of Canada. In 1924, he was one of the first to join the newly formed Royal Canadian Air Force, his number being C3. The outbreak of war in 1939 found Canada unprepared and it was due to Air Commodore Stedman that the Engineering services were quickly organized. He was eventually promoted to Air Vice Marshal as Air Member for Aeronautical Engineering on the RCAF Council. Then, as the need for a more vigorous policy of research became evident, he was promoted to Director General of Research. It was in this capacity that he wrote the memorandum which started the investigation of turbojet engines in Canada. He was awarded the O.B.E. and C.B. for his outstanding military service.

On retiring in 1946 from the RCAF, he joined the staff of Carleton College, Ottawa, and was largely responsible for the excellent reputation of that institution for engineering training. He also took a great interest in the National Research Council, serving on several committees.

In 1952 he retired from Carleton College and devoted his time to writing his memoirs concerning aviation. He was elected an Honorary Fellow of the C.A.I. in 1955 and later served on its Education and Training Committee.

Air Vice Marshal Stedman left his imprint on a wide circle of friends in many countries. He belongs to those of whom it is said, "Their Name Liveth for Evermore".

Toronto T. R. Loudon

ADMISSIONS

At a meeting of the Executive Committee of the Council, held on the 15th April, 1957, the following were admitted to the grades of membership shown.

Associate Fellow

Dr. H. Cabannes, Exchange Professor of Aeronautics, Laval University, Quebec City, P.Q.

H. Louis (on transfer from Member)

C. V. Olver, Chief Development Engineer, Ferry Airports Ltd., Surrey, England: *Robins Wood, Bransgore, Nr. Christchurch, Hants., England.*

Member

A. W. Baker, Sales Manager, Garrett Manufacturing Corp. of Canada Ltd., Rexdale, Ont.: *2228 Bartlett Lane, Applewood Acres, Port Credit, Ont.*

E. W. Baker, Engineer, Trans-Canada Air Lines, Winnipeg, Man.: *3809 Cuthbertson Ave., Varsity View P.O., Man.*

***Member* (Cont)**

R. G. Bell, Chief Illustrator, Northwest Industries Ltd., Edmonton, Alta.: *10735-103 St., Edmonton, Alta.*

S/L G. W. E. Brown, Chief Technical Services Officer, RCAF Stn. Sea Island, Richmond, B.C.: *2877 W-23 Ave., Vancouver 8, B.C.*

S/L L. C. Card, Sr. Telecommunications Officer, RCAF Stn. Cold Lake, Alta.: *Box 1280, MPO 503, Grande Centre, Alta.*

A. G. Clarke, Supervisor Instrument Design, Orenda Engines Ltd., Malton, Ont.: *31 Densmore Ave., E. Rexdale, Ont.*

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MEMBERSHIP OF THE C.A.I.

as at the Meeting of the Executive Committee of the Council on the 15th April, 1957.

Technical	**1834**
Associates	**78**
Total	**1912**

The Technical grades comprise the following:

Honorary Fellows	10
Fellows	24
Associate Fellows	209
Members	967
Technical Members	479
Technicians	32
Students	113

SUSTAINING MEMBERS

NEWS

Canadair Limited has completed the modification work on a B-47 which will serve as a flying test bed for the Iroquois. The aircraft was delivered from Cartierville to Toronto on the 15th April. The photograph below shows the pod, containing at present a mockup of the real engine, mounted under the starboard tailplane of the B-47 and gives a good indication of the size of the engine.

The aircraft is on loan to the RCAF from the USAF, which has also provided ground handling equipment and checked out the Orenda test pilots, the first civilians from another country allowed to fly the B-47.

Orenda Engines Limited placed a contract on Canadair for this project, which has involved over 50,000 manhours for manufacture of the pod and attaching pylon and for installation of the necessary instrumentation in what is normally the aircraft's bomb bay.

Spartan Air Services Limited staged the official opening of their new helicopter service plant at Uplands Airport, Ottawa, on the 12th April. The opening ceremony was performed by the Hon. George Marler, Minister of Transport.

The right-hand photograph shows the interior of the main shop; smaller ancillary shops and stores are arranged round it. The total plant area is 14,000 sq ft; main shop area 6,400 sq ft; other shop area 4,400 sq ft; and 2,000 sq ft of classrooms, for the extensive training course operated by the Company for helicopter engineers and pilots.

Inspection and repair equipment installed for the maintenance, overhaul and rebuild of helicopters includes the most modern equipment available, such as the Magnaflux, a magnetic crack detector; the Zyglow, a non-ferrous metal crack detector; gas welding equipment, special tools and fixtures; engine power pack build-up stands and fixtures; paint strippers, degreasers and self-contained sealed water-washed paint spray room.

These facilities are backed up by Spartan's fixed wing shop at Uplands, machine shop, sheet metal, electrical, radio and plastic shops.

The plant is already servicing helicopters for the RCN, RCAF and commercial operators, as well as supporting the Company's own fleet of 22 Bell aircraft.

Avro Aircraft Ltd. announces some changes in its Engineering Division's training program to cater more exactly to the requirements of the Engineering Division and also provide the Technical School graduates with an opportunity to enter the field of Engineering.

At this time the school is conducting three courses of study for applicants who can meet the following qualifications:

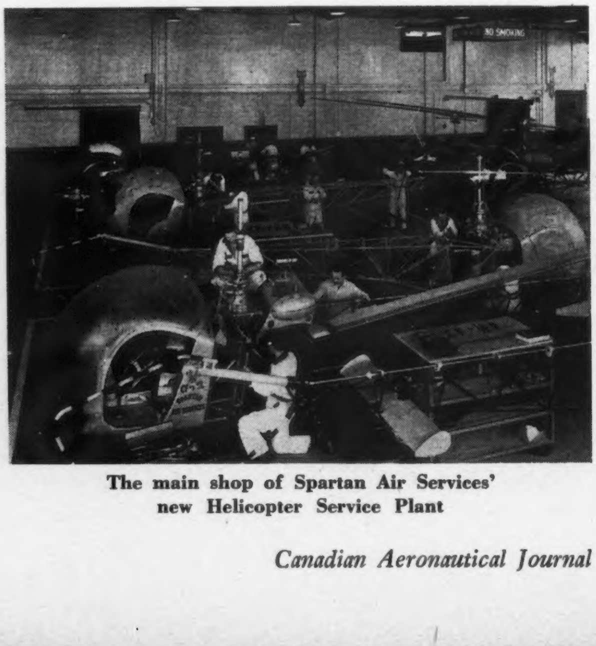
Course A – Grade XIII or equivalent and a thorough knowledge of mechanical drafting. Training period is 19 weeks and during this time students receive instruction in aircraft systems, such as electrics and radio, hydraulics, flying controls, power plant installation, fuel and air conditioning. They also learn the technique of forging, casting and extrusion as applied to modern aircraft design; full scale drafting technique and aircraft drafting with emphasis on the use of standards as specified in the engineering manual. Also a thorough study is made of materials and processes and shop technology.

Course B – Grade XII graduation diploma in mechanical drafting from a technical school. Training period is 30 weeks and the course content is identical to that of Class A with the addition of Grade XIII mathematics and physics. The curriculum as issued by the Department of Education for the Grade XIII courses in algebra, geometry, trigonometry and physics is used, thus enabling the students to write the departmental examinations in these subjects if they wish to do so.

Course C – Graduates from Course A or B who have spent a period of time in the Design Office are eligible. This course is also open for those who have gained considerable experience in the Design Office and can meet a Grade XIII or equivalent standard of education. Training period for this course is approximately 23 weeks and is given on a part time basis. Subjects covered are: mathematics – a continuation of high school trigonometry and geometry and instruction in basic calculus; strength of materials – to give the draftsman the background to carry out preliminary stress calculations on his own design, from simple machined fittings to the determination of loading curves for beam sections.

Since May 1955, eleven classes have completed the various courses, for a total of 103 graduates. At the present time there are 40 students.

The Iroquois pod on the B-47 flying test bed



The main shop of Spartan Air Services' new Helicopter Service Plant

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of the

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1957-58

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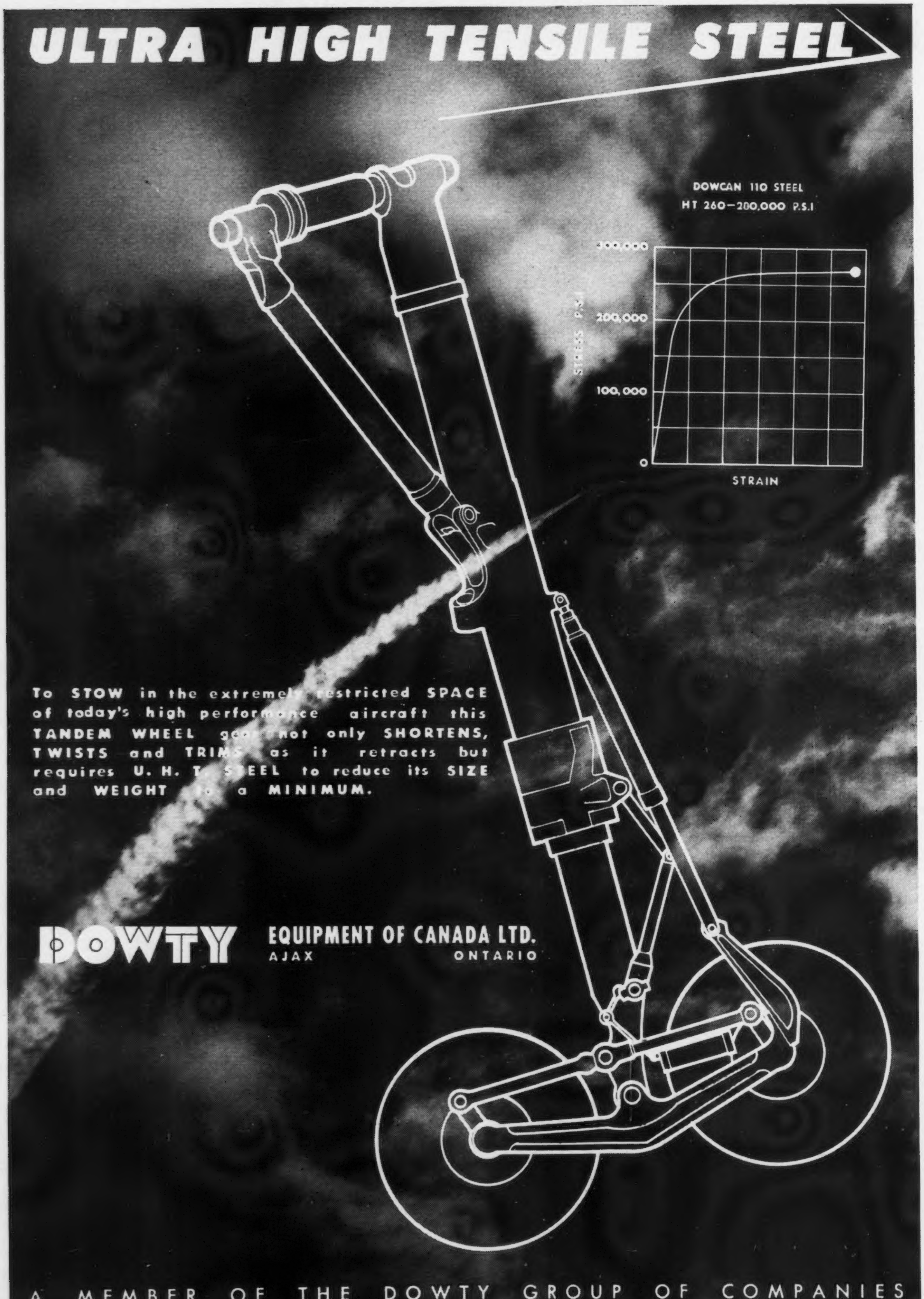
LIST OF MEMBERS

Members are reminded to complete the buff cards sent to them with their dues bills and to return these cards to C.A.I. Headquarters before the 31st May, 1957.

Otherwise their listing in the List of Members, 1957, may be inaccurate or incomplete.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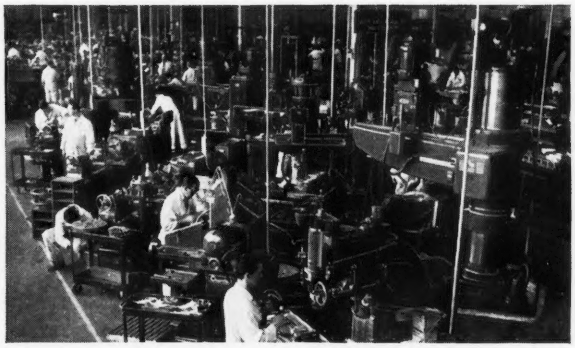
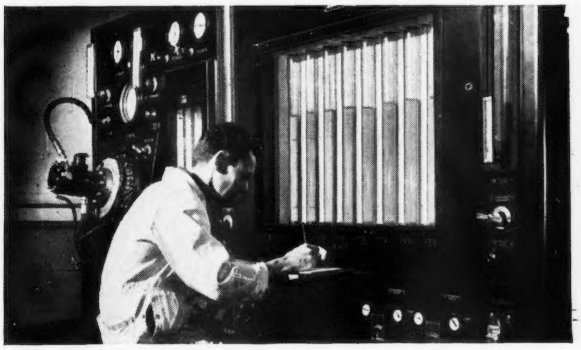
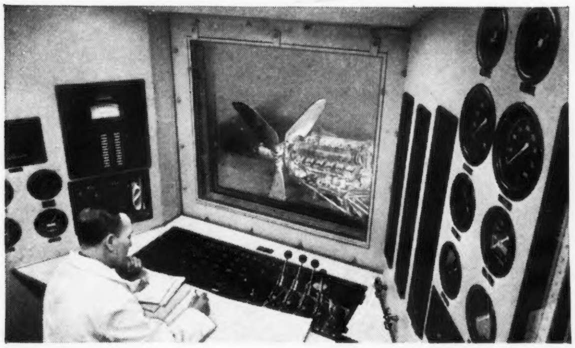


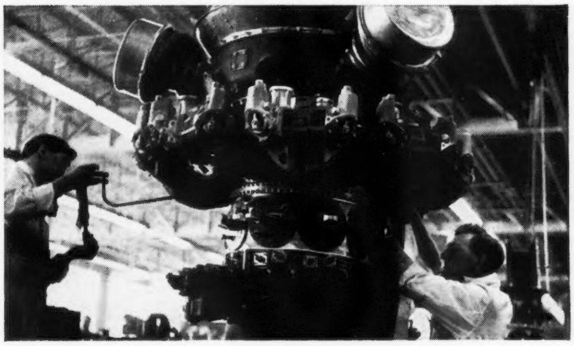
With 180,000 square feet of floor space and about 650 employees, this is the largest plant of its kind in Canada.



This modern test equipment calibrates the overhauled fuel system prior to final assembly.



All details of engine behaviour and performance are checked in these well-equipped test cells, which are also the largest of their kind in Canada.



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